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Climate Analysis for Urban Planning

Proceedings of a Japanese-German Meeting
Karlsruhe, September 22-23, 1994

K. Höschele, M. Moriyama, H. Zimmermann (Eds.)
Institut für Meteorologie und Klimaforschung

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"Klimaanalyse für die Stadtplanung"

- A small Japanese-German Meeting -

都市計画のための
気候解析
独日小会議

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* paper not available

PREFACE

For nearly ten years lively contacts have been maintained between the Department of Architecture and Civil Engineering at the Kobe University, Japan, and the Institut für Meteorologie und Klimaforschung, Forschungszentrum Karlsruhe/Universität Karlsruhe (IMK). The idea of organizing a scientific meeting under the heading "Klimaanalyse für die Stadtplanung" with an increased attendance had been conceived in that cooperation by Dr. Moriyama during his 10 months stay at the IMK.

The meeting took place in Karlsruhe on September 22 and 23, 1994. About 40 participants, among them 18 from Japan, attended the event which had been organized by Prof. K. Höschele, IMK, Dr. M. Moriyama, Kobe, with assistance by H. Zimmermann, IMK, and H. Miyazaki, Sanda, Hyogo.

There have been remarkable developments in climate analysis in recent years. They make evident that this topic commands particular interest, both in the research sector and in practical planning. Considering the general increase in environmental consciousness, it is required to a growing extent to take into account the specific climatic conditions of the region or of the site in planning towns, settlements or individual buildings.

The climate and the conditions of life are different in Japan and in Central Europe; but the growing number of similar environmental problems and the development of similar scientific tools to analyse and to tackle these problems, are promising preconditions for a Japanese-German cooperation. Several participants of this meeting had already attended preceding conferences and symposia: "Climate–Building–Housing", Karlsruhe University, 1986, "Urban Climate, Planning and Building", Kyoto, 1989, "Planning Applications of Urban and Building Climatology", Berlin, 1991 and CUTEST'92, Tohwa University, Fukuoka. Now they used the opportunity of this meeting to report on the current state of their studies and to present new results.

The issues of "Klimaanalyse für die Stadtplanung" have been presented in 14 papers and 14 posters. The afternoon of the first day of the meeting was devoted to four detailed review papers, the second day to shorter presentations and poster discussions. The individual topics were related to:

- Measurements in the urban boundary layer.
- Means of satellite assisted remote sensing in urban climatology.
- Numerical simulations of atmospheric processes in urban and rural areas.
- Methods of classifying the climatic conditions in towns.
- Influences of the mesoclimate on urban planning.
- Legal requirements concerning urban planning.
- Energy exchange between buildings and their environment.
- Impacts of urban settlements on the distribution of precipitation.
- Practical implementation of climatological knowledge in urban planning.

With the publication of all available papers and posters presented at the meeting we intend to address a larger community and to give incentives to do research work, apply knowledge of climatology, and promote communication at an international level. We are gratefully appreciating the cooperation by the authors.

Further we would like to thank all individuals and institutions for their support and for the contributions to the success of this meeting, in particular:

Universität Karlsruhe – Forschungszentrum Karlsruhe,

Study Group "City Climate of Osaka", supported by the Building Research Institute, Japanese Ministry of Construction,

Study Group "Ecological City"/Committee of the Architectural Institute of Japan.

Karlsruhe, October 1994

K. Höschele
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H. Zimmermann

URBAN PLANNING IN THE UPPER RHINE VALLEY THE IMPORTANCE OF CLIMATIC ASPECTS

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ABSTRACT

The upper Rhine Valley from Basle in the South to Strasbourg, Karlsruhe and Mannheim in the northern part belongs to three countries, Switzerland, France and Germany. Scientists of these countries are collaborating within a Regional Climate Program (REKLIP) in a thorough climatic study of this geographical unit. The structure of the valley, forming a flat trench or "Graben", roughly in a South-North direction, creates some particular climatic features with consequences for urban climate and planning.

Air flow will be channeled; the emission of smoke from stacks will generally follow the axis of the valley. The formation of rather thick inversion layers in the valley and the reduction of wind velocity will frequently impair the dispersion of pollutants. Consequences for planning are the proper location of industrial plants, high stacks and, more important, the reduction of emissions, for instance by district heating or by the development of urban transport systems. Local wind systems at the border of the Rhine valley modify the dispersion of emissions from sources near the ground and may carry fresh air to settlements. Important for planning is to preserve catchment areas and ways for the transport of the nocturnal down-slope flows. A very important issue in the comparatively warm Rhine valley is heat load in summer. Urban and building planning has to prevent a further enhancement of heat stress in the city by various measures.

The seasonal, diurnal or synoptic changes of weather conditions in time can be partly matched in the city by structural changes in space, for example by offering pedestrians a pattern of either protected or open footpaths and places.

1. INTRODUCTION

In the whole area of the upper Rhine valley, beginning from the southern end in Switzerland with larger cities as Basle, continuing with Freiburg, Strasbourg in France, Karlsruhe and finally Mannheim/Ludwigshafen in the northern part, urban planning has to cope with similar climatic characteristics. They are a consequence of the structure of this valley, a broad and flat trench, extending over 270 km or latitudes from 47° 30' N at the southern to 50° N at the northern end. The Rhine-"Graben", was formed by sinking and lifting processes, starting in the Tertiary period about 50 million years ago. It was modified by processes of water and wind erosion, especially during the ice age of the following Quaternary period. The bottom of the valley, a plain 35 to 40 km wide, is about 90 m above sea-level near Mannheim, rising to about 250 m at the Swiss/German border near Basle. Particularly the southern part of the valley is surrounded by rather high mountain chains, Black forest (Schwarzwald) on the eastern, German, side and Vosges (Vogesen) on the western side in France, with peaks, reaching to a level of more than 1000 m above the plain.

2. MAIN CLIMATIC CHARACTERISTICS

In a macroclimate with prevailing westerly and less frequent easterly winds, the so-called "temperate climate" of Central Europe, this orographic structure creates some particular climatic features:

1. Due to the sheltering effect of the mountains wind velocity in the valley may be reduced and up to the top level of the surrounding mountains wind direction is deflected to directions parallel to the valley axis.
2. On the leeward side of the bordering mountain chains cloud cover and precipitation may be reduced (for the prevailing west winds this is the eastern side of the mountains or the western side of the valley plain); as a consequence in these areas duration of sunshine and global radiation is enlarged.
3. Due to the low height above sea level ambient temperature ist comparatively high, the same applies to water vapor content. In summer the combination of warm, humid air, high radiation and low wind velocities often produces heat stress. For people in large cities this load is further enhanced by the urban heat island.
4. In weather situations with clear sky or few clouds stable inversion layers are formed at night, from ground to a height of several 100 m, preventing the dispersion of air pollutants – in winter these layers may last for several days, combined with the formation of fog and an accumulation of air pollutants.
5. The slopes, bordering the upper Rhine valley, produce a nocturnal cold air flow, which is rather strong at the edge of the plain. Near the surface this flow is slowing down after a distance of about 1 or 2 km. At the outflow of very large side valleys the outflow may almost reach the centre of the Rhine valley, occasionally in a level some 50 or 100 m above ground.

Most of these particular characteristics of the climate in the upper Rhine valley have positive and negative aspects for people, living in this region. It depends on season, time of day, large scale weather situation or individual expectations. Urban planning has to take into account these climatic conditions, making use of favourable properties and mitigating extreme climatic strains.

3. CONSEQUENCES FOR URBAN PLANNING

Returning to the climate features as stated above, we will discuss some more details and consequences for urban planning.

Point 1: The channeling of air flow in the valley is important for the location of industrial plants: dispersion of pollutants will follow the axis of the valley. Figure 2 contains the frequency distributions of wind direction and velocity from our measurements at meteorological towers of Badenwerk AG, Karlsruhe. The stations Wyhl and Freistett represent the southern and central part of the valley, with strong channeling, especially for higher wind velocities. At Freistett, the gap between the mountains of Vogesen and Pfälzerwald at the western boundary of the Rhine valley, produces a small increase of westerly wind directions.To the north, the height of the bordering mountains decreases; between Schwarzwald and Odenwald the hilly Kraichgau area with heights less than 300 m marks the eastern boundary of the Rhine valley. At Philippsburg the channeling is reduced and in addition the valley axis is bending from Southwest to North. The result is an *Y*-shaped distribution of wind directions.

Reduced wind velocities and a stable stratification of the atmosphere (*Point 4)* are reasons to build high stacks in order to reduce maximum concentrations near the ground. These are measures to avoid strong local pollution loads. In order to improve regional air quality, it is necessary to use all possibilities for a reduction of emissions. One effective measure has been the expansion of district heating, another the development of urban transport systems and their link-up with regional systems.

Point 2: Upwind and downwind effects are important for the choice of sites for fruit- and wine-growing or for health-resorts at places with less rain and much sun radiation. Also involved are the phenomena under *Point 5*, orographic induced wind systems at the border of the Rhine valley. They may cause frost damage in vineyards, orchards or other sensible plantations – on the other hand these wind systems may carry fresh and cool air to settlements near the edge of the plain. Change of land use, for instance afforestation in the catchment area of cold air is a means to prevent frost damage without impairing very much the supply of fresh air to settlements in the valley. The expansion of the built-up area of a city in the main valley, including the slopes and side-valleys, will prevent the production and supply of fresh air to the bottom of the valley. There will be a conflict in urban planning, because these slopes are preferred sites for building houses.

With the support of the city administration we have installed in Karlsruhe a network of 13 stations for measuring surface wind at the eastern border of the Rhine valley. They are situated within the range of typical topographic structures. The statistical analysis of the bulk of data has the objective, to describe diurnal and annual variations as well as correlations with large scale meteorological conditions. The results indicate a strong nocturnal cold air flow directed to the Rhine valley; the opposite component during the day is weak compared with the stronger flow parallel to the Rhine valley. Figure 3 presents an example for a typical wind-rose in this area (Grötzingen1). The southeastern wind is the outflow of a side valley (Pfinztal), with a maximum frequency in summer nights, starting at sunset and ending 2 or 3 hours after sunrise. In an annual average the frequency of this down-valley winds comes up to 40 % during nighttime.The cooling effect is the result of an increased heat transfer at wind velocities of 2 - 3 m/s or more and a sharp stepwise decrease of temperatures, typically 2 °C, after the onset of the drainage wind. In addition these local wind-systems have an influence on the dispersion of pollutants, for instance odours from sources near the ground. Odour nuisance problems near the station Grötzingen 1 have been the cause for starting the installation of this network of measuring stations

The issue of *Point 3* and especially an issue of the last very hot summer with maximum temperatures up to 38 °C has been heat load. With a wet-bulb temperature of 18 °C as a lower limit, the annual average of hours with heat load in the plain of the Upper Rhine Valley is 4 % of the total time, in the centre of cities 7 %, increasing to 10 % in hot years. A measure to reduce the heat island effect in the city is to restrict the extension of contiguous settlements to a maximum diameter of for instance 1 or 2 km. Another measure is the design of a system of some broad ways parallel to the main wind directions with branches of many smaller passages for the transport of air from the surrounding area or from large park areas, covering 500 000 m^2 or more, to the city centre. Further means to reduce the heat load are roof gardens, green walls and broad-leaved trees, giving shade only during the summer season. This "green program" has played an important role in Karlsruhe, in urban as well as in building planning.

On the level of building planning there are even more possibilities: with a proper design of walls and windows there is no need for air condition, producing waste heat in summer and less need for heating, producing air pollutants in winter.

For the problem of making a city liveable under contrasting weather conditions – hot or cold – stormy or calm – clear or cloudy sky – rain, snow or periods of drought – a small scale pattern of spots and lines, places and footpaths, may be a solution. The presence of open, exposed places and others, protected against rain wind or sun, will help the pedestrian to find a proper way through the city or to stop at a pleasant place for resting.

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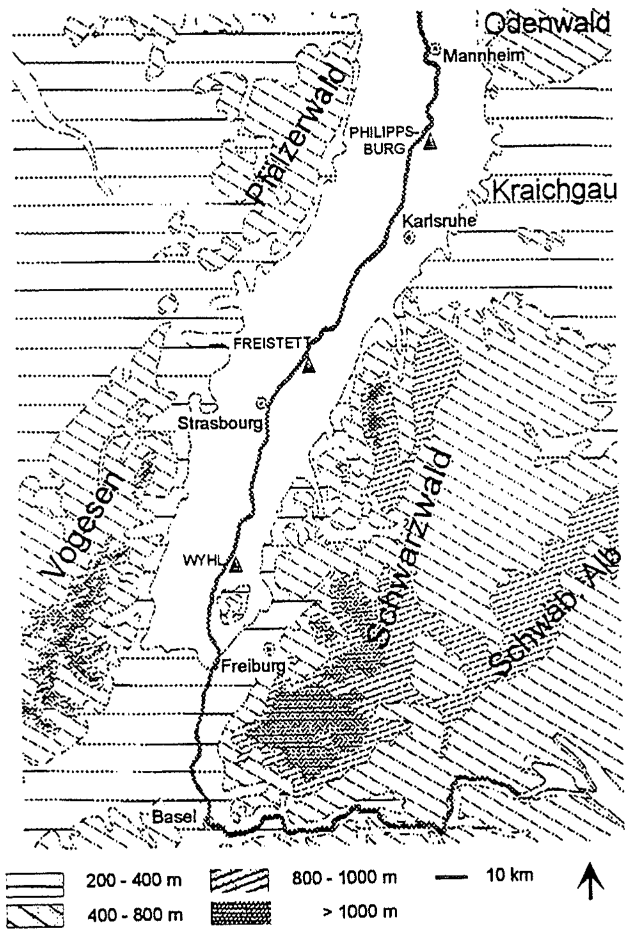

Figure 1. Situation of the upper Rhine valley with major cities and sites of meteorological towers.

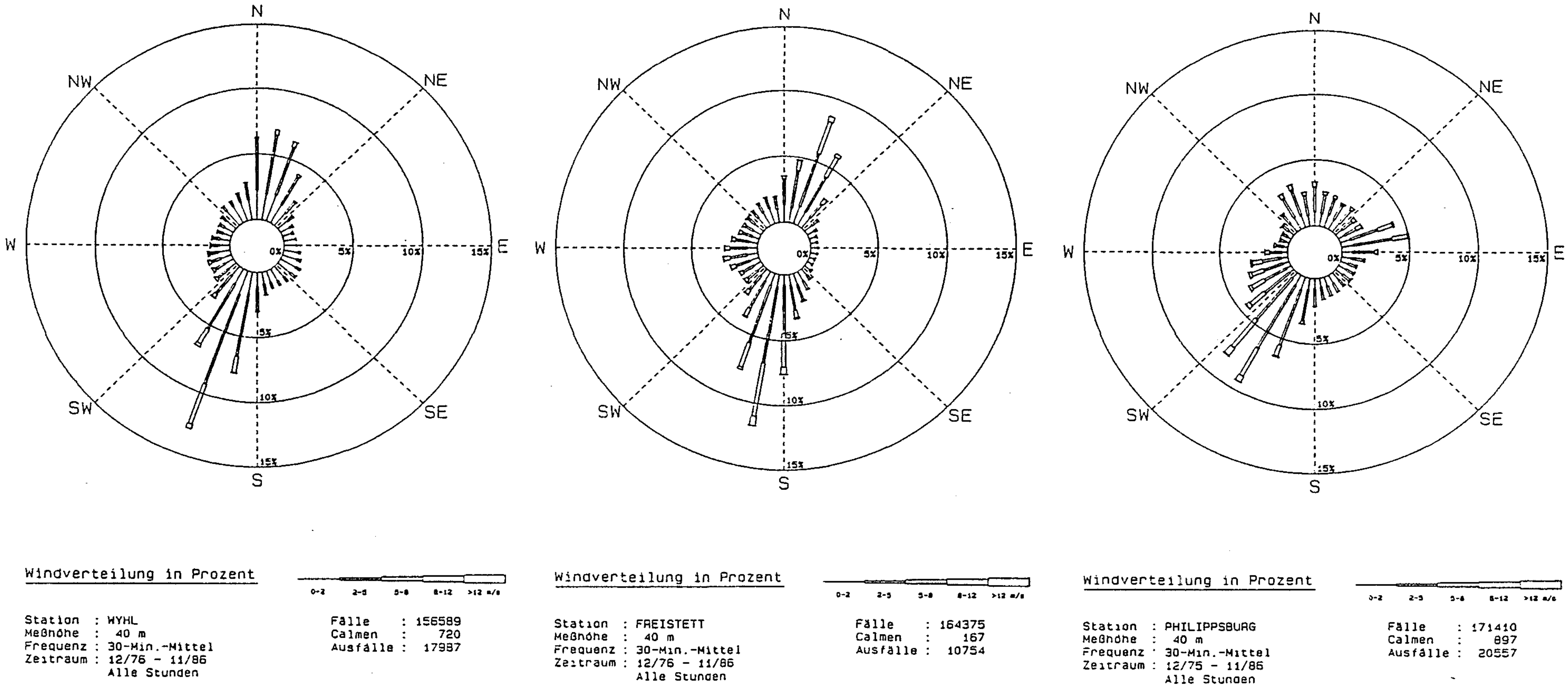

Figure 2. Frequency distribution of wind direction and velocity, 40 m above ground, from measuring towers in the southern (Wyhl), central (Freistett) and northern (Philippsburg) upper Rhine valley, Dec. 1975 - Nov. 1986.

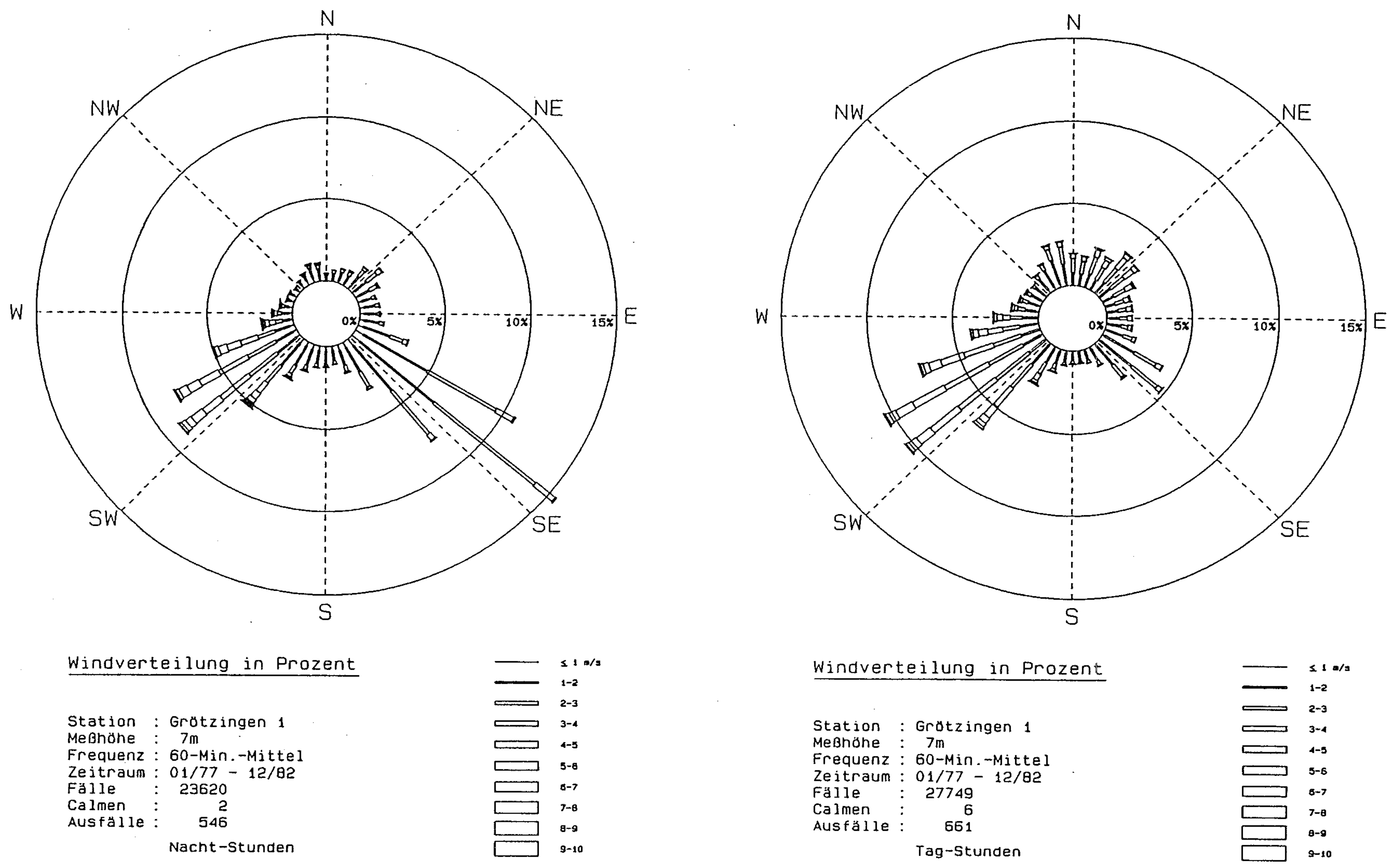

Figure 3. Frequency distribution of wind direction and velocity at nighttime (left) and daytime (right), 7 m above ground, at the outflow of the Pfinz valley into the upper Rhine valley near Karlsruhe, Jan. 1977 - Dec. 1982.

THE CLIMATIC ANALYSES IN THE RUHR AREA

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ABSTRACT

The Ruhr region is a large conurbation with many industrial and urban centres, consisting of 11 cities and 4 country districts. The large scale assessment of climatic data started in 1970 with a program of "Thermal Mapping" from aircraft, completing the sparse data base of already existing observational data. Later on sattelite data have been included additionally. A main issue of our group is to implement the results of climatic analyses in recommendations for regional and urban planning.

1. INTRODUCTION

Intensive scanning flights across the Ruhr area marked the early work done in the field of climatology in that region. These data should contribute to a further development of the classification of the Ruhr area with its typical green belts. These important green lungs still have climatic compensatory functions nowadays. The use of satellite data led together with that flight data to a climate expert's report. This was the basis on which we developed a climate map of the Ruhr area in 1992.

In 1979 new legislation came into force with the effect that it wasn't any longer possible for the SVR (Siedlungsverband Ruhr) to carry out planning tasks and the whole association became more service-oriented. Additionally this led to a different responsibility concerning climatology. From that time on our work hasn't any longer been concerned with the region as a whole, but rather we have worked more and more on climatic surveys for certain cities. In the beginning this was done on the basis of thermal data only, for example in the cases of Duisburg and Hagen. Time by time we increased our possibilities by purchasing measuring vehicles and equipment. Since 1980 there has been a group of 4 - 6 people only concerned with producing climatic surveys for urban areas, ranging in size from whole towns down to districts or even blocks.

2. IMPLEMENTATION OF CLIMATIC ASPECTS INTO THE PLANNING PROCESS

From the beginning we were aware that the clients of our surveys are no climatologists; generally they have rather poor climatological knowledge. Consequently our reports should be understandable and summarize the most important facts and results on a map. The aspired clear spacial orientation had to be done in the largest possible scale in order to use the results in the urban planning process. In addition to the popular presentation and the spacial orientation a third aspect had to be considered. Usually a lot of cities don't have adequate references on their climate. Frequently those are scattered in scientific publications, often too vague and on a too small scale to be taken into account in the development plan.

First it was therefore important to produce a climate map on the scale of the land utilization plan. This map divided the urban area into climatopes in order to give the planners (among others) a rough idea of the way the town's climate is influenced by geomorphology and buildings. The first attempts had to be made with very few of our own measured data but we could build up a good basis of measuring equipment and methods in the course of time.

Since the beginning there has been the problem of incorporating our results in planning recommendations. This has been made more difficult by the fact that there were and are no precedents. It isn't possible to develop a town from the climatic point of view only without taking socio-economic and cultural aspects into account. On the other hand some people think that climatic problems aren't important at all.

3. FUNCTION MAPS

That are the reasons why we developed a map containing planning advice for the whole urban area. This map is evaluating the town in its present state from a climatic viewpoint. The planning advice is meant to have a positive influence on the further development of the urban area. Without any guidelines or limit values to orientate on and even without a common opinion in the municipalities regarding the ecological urban planning, we had to develop our own conceptions. As for the synthetic function maps these should be easily understandable, simple and not too detailed. The basic idea was to define greatest possible areas assuming a higher-ranking long-term climatic function. All the detail planning was built around this framework. Obviously such a map can't satisfy every stage of the planning process, given the very different aims of landscape planners, architects, ecological orientated planners and the administration of finances. Consequently our map can content the planners only partly and represents just a basis of further discussion. Moreover climatic reports aren't a legal requirement.

4. METHODS

We made climatic analyses nearly for all towns in the Ruhr area. We definitely surveyed more than 20 towns and communities within the last two decades making us the group with the highest number of such analyses in Germany. Pursuing applied climatology our fundamental aim is to process the available knowledge regarding urban climate, to verify this for every city by taking measurements and to push ahead with the spacial classification of the urban area from the climatological point of view.

For this reason we developed a method which we used in all our surveys. Basically it consists of two procedures. The first consists of processing and evaluating the measured data which forms the basis for the urban climate analyses. The second involves analysing the factors affecting the climate. Obviously a change of climatic factors results in an alteration of the urban climate. Therefore we particularly promoted the interpretation of relief, landuse and, due to our tradition, heat images.

For a number of years the KVR (Kommunalverband Ruhrgebiet) has been investigating the real landuse on the basis of aerial photographs which are stored digitally and are usable for our purposes. A map of the urban structures relevant to the climate is averaged out of more than 100 landuse categories, giving us first insights into the organisation of urban climatopes. The influence of relief on the climate is well known but, as relief plays a minor role in the Ruhr area, I don't want to pursue this point here.

Since 1970 the KVR has been carrying out thermal measurement flights and I personally worked intensively on the interpretation of this data in the last two decades. We made thermal measurement flights across nearly every urban district in the Ruhr area. The last one took place in Düsseldorf in 1993. I would like to stay a little longer on this subject. Normally our thermal maps have a resolution of 7 - 10 m per pixel. This resolution is suited for urban climatological investigations. In my opinion an area should be flown over twice, preferably during summertime high-pressure conditions, to gain the most autochthon conditions possible. Both flights should take place within 24 hours, at times with maximum and minimum surface temperatures respectively. For example the Düsseldorf flights were done on 30.06. at 15 CET and 01.07. at 03 CET.

Nowadays digital picture processing is very advanced and data can easily be processed radiometrically as well as geometrically. The presentation of different flight path strips is no problem anymore. We perform the high resolute interpretation on the computer, as all data including the processed data is digitally stored. We developed our own climate-geo-information-system for Düsseldorf, consisting of all the initial data as well as its evaluation stored on a computer in processed form. Experimental data of vertical soundings and ground based stations, vehicle based measurements and air pollution data are stored in this system additionally.

5. RESULTS

The results of the Düsseldorf scanning flights are maps of the surface temperatures for the daytime situation, the nighttime situation and a combination of both, as well as a map of the vegetation index and one of the ground-sealing of blocks. The day and night surface temperatures are color-coded. These colors aren't ordered in a continous color scheme like usual, but chosen that low temperatures represent open country temperatures with shades of blue, while high temperatures, occuring only in urban areas, are depicted in warm colors like yellow and orange up to red. The result is a very clear representation, reflecting the well known fact, that the town is warmer than its surroundings by day as well as by night. The highest daytime temperatures are generally measured on roof surfaces. At night the most reddish colors are found on streets or at building walls. These facts often were demonstrated and I tried to describe the relationship with air temperatures.

Far more important is the very good classification of the city in climatopes due to the thermal pictures. This classification is supported by the vegetation map and the map showing the degree of sealing. With our measured data we even could draw a clear connection between the degree of sealing and the air temperature. By raising the degree of sealing by 10 % the average annual temperature would rise by about 0.2 K.

While thermal mapping offers information of large surface areas at a particular moment, classical measurements cover longer periods of time but represent small parts of the town only. Our climatic measurements in urban areas were performed at 5 - 10 stations and by measurement vehicles driven around in town. In Düsseldorf we built up 10 stations and conducted about 30 measuring tours. With the help of a captive balloon we measured the vertical temperature- and windfield during three measuring periods.

All measurements and climatic factors were summarized in a report and concentrated in the climate function map. Primarily the climate map shows the climatic classification of the investigated area rather than the measured data. This map was first developed for Duisburg about 17 years ago and the latest one is currently prepared for Düsseldorf.

6. RECOMMENDATIONS FOR PLANNING

Previously I mentioned that we produce these maps for cities which would like to have an additional planning advice. Those maps actually should contain an evaluation and derived planning references. Some people believe that climatologists should only conclude from measurements and objective conditions and afterwards should complete the climatic map with planning advice. In contrast we believe, that a seperate map with planning instructions is a more sensible option, because the spacial orientation can depict recommendations from larger scales down to the local scale with different sharpness much better.

Finally it is important to realize, that there is no direct connection between the measured values and the planning advice. Put another way, certain climatic effects can be achieved by following different planning recommendations. The goal always is to improve the current situation. Normally there is no uniform opinion on the extent of the changes. The planning advice map of Dortmund was the first developed by us. For Düsseldorf we make a first step towards the production of a so-called planners manual which will give very detailed recommendations as well as information on urban ecological planning arrangements.

It is impossible to trace back to what extent our surveys have led to improvements in the quality of life in the cities of the Ruhr area. But it is certain, that the climatic situation in this region has improved and will continue to improve in future; our studies and reports certainly have made their contribution to this development.

URBAN CLIMATE AND URBAN PLANNING
- THE EXAMPLE OF STUTTGART -

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ABSTRACT

Climate and air quality are two important aspects for urban planning. In Germany these factors have to be taken into consideration, required by the law for planning and building. It is shown, in which way in Stuttgart these requirements are taken into account in municipal planning.

The working methods of the departement of climatology in the office for environmental protection are introduced as well as the influence in urban planning. On the basis of an investigation (Klimaatlas) specialities and problems of the urban climate are discussed. Furtheron it is shown, on which way climate and air quality can be taken into consideration in urban planning, in order to improve the local situation. It is especially important to protect zones with cold air flow and to reduce air pollution, especially produced by car traffic.

1. THE DEPARTMENT OF CLIMATOLOGY

Earlier than other cities Stuttgart began to involve municipal climatologists in urban planning. This can be traced back to the fact that the air quality of Stuttgart was not very good in earlier times. This is because the city lies in a basin and the mean wind velocity is only about 2 m/s and temperature inversions occur frequently.

In the year 1699, when the buildings in Stuttgart were usually only one storey high, it was proposed that they should be raised to two storeys. Members of the Council were against this plan, because they said that such high houses diminish the flow of fresh cold air in the city basin and that an increase in illness and disease would be the result. You can imagine that these warnings were not very successful because like many of its surrounding cities, Stuttgart is today a great industrial centre in the Federal Republic of Germany, and there are now buildings in the city with much more than two storey.

In 1951, recognizing the problems of air pollution climatology, an office for Urban Climate was established in Stuttgart. It is a municipal institution, so activities are mainly limited to within the borders of Stuttgart, where about 570 000 people live. The main fields of study are climate, air pollution and noise. The development of this department from two members in 1951 to nine members today, shows the great importance accorded to environmental protection in connection with the rapid technical and economic development of industry in Stuttgart.

The department's activities are very many-sided, and there are to solve many problems about air quality, urban climate and planning, also there are many interactions with other municipal offices. More than 50 % of the work is together with the cityplanning office. It has been increasingly necessary to get detailed values about both the air pollution conditions in Stuttgart, and also about the meteorological parameters. This requires buying expensive instruments, including an automated station for air quality control and a mobile measuring station. The maintenance of all the instruments is conducted by our own personnel.

A great advantage in the work is that the activities cover not only climate but also air pollution concerns. It is important to mention that we not only plan and carry out measurements, we also interpret the results and give advice to the planners, based upon these results.

2. CLIMATE INVESTIGATION FOR THE REGION OF STUTTGART (KLIMAATLAS)

On the basis of a climate investigation for the region of Stuttgart the working methods of the department of climatology are presented as well as the consideration of the results in urban planning. Considering the actual discussion about new building areas basic investigations become more and more important to guarantee a qualified master plan for urban areas. Thus the department for climatology in the office for environmental protection was charged with an extensive climate investigation for the region of Stuttgart by the city of Stuttgart and by the surrounding cities (Nachbarschaftsverband Stuttgart, 1992). It was the aim of the investigation to work out maps showing the climatic analysis of the region and to elaborate maps with deductions for planning, zoning and building. The planners should be enabled to take into account climate and air hygiene in city planning in a better way.

The more concrete and the more convincing the problems of urban climate and air pollution are exposed, the greater is the possibility to take into account these facts in urban planning in a proper way. Besides of the representation of urban climatic facts the planners are very interested in a climatic valuation of buiding areas and in deductions for planning, building and zoning for a climatic optimization of urban schemes, new projects and for readaptation.

Part of the investigation for the region (1000 km^2) was an infrared remote sensing, wich made it possible to get an overview of the superficial soil temperature distribution of the whole region on a suitable day. In this way it is possible to recognize the differences in temperature between the various parts of the region (for example heat islands, areas with flow of cold air, areas with stagnating cold air). Doing at least two flights, in the evening and in the early morning, allows to get informations about the differences in the nightly freshening for the various areas. It is also the aim of the infrared-thermography to get hints on areas with local winds or on building structures which are in conflict with urban climate. The infrared thermography also allows to find appropriate places for further climatic measurements. These conclusions however make it necessary to have a realistic understanding of climatic processes in the atmospheric surface layer. A good knowledge of the local relief of terrain and of the local zoning is required in order to interpret infrared measurements.

Another part of the investigation were extensive climatic measurements, done by the Deutscher Wetterdienst during one year at twelve measuring points. Using a special statistical model (Gerth, 1986) and the digital orographic model it was possible to elaborate maps of the different elements of climate (air temperature, wind speed, frequency of low wind speed and thermal comfort).

Data on air pollution were taken into account using the maps on the emissions and immissions, which exist for the region of Stuttgart. Furtheron the data of the available measurements at different fixed measuring stations for air pollution were considered (Ministerium f. Umwelt Baden-Württemberg, 1989, 1990).

Aerial views of the region were further materials for the interpretation.

The results of the investigation were summarized, elaborating maps with basic elements and a map with a extensive climatic analysis in scales of 1:100 000 and 1:20 000 (scale of the master plan). In the map of climatic analysis the region is classified according to the specific climatic characteristics (Klimatope). Furtheron cold air flow, cold air lakes, regional winds, specialities of emissions and some more facts of urban climate are represented in this map as well as the concentration of air pollution (3 classes of an air quality stress index) and all the streets with high motor car exhaust. The legend of the maps contains symbols which shall be standardized further on by a (not obligatory) national standard (VDI 3787-1, in preparation).

Finally maps with deductions for planning, building and zoning were worked out. These maps are important for the planners and also for the communal politicians, which decide on urban planning and which have to take into account climate and air quality. In these maps the climatic facts are evaluated as far as concerned aspects of planning. The different areas are marked according to their sensitiveness against modification in landuse. So they give advice to the planners what to do for urban climatic optimization of new projects and readaptation.

In the region of Stuttgart, which is characterized by low winds and frequent temperature inversions, especially local cold air flow during the night on the slopes are important. These slopes and also some of the valleys should be without any buildings, or if there exist already building areas they should be readapted concerning the climatic point of view.

Fig. 1 shows for a planning area in a slope-situation the positive influence of considering climate in planning. So the original small free green zone was enlarged to guarantee an effective zone with flow of cold air.

As far as concerned air pollution motor car exhaust is the main problem. For example the standard for nitrogendioxid and benzene immissions are exceeded near streets. Counter-measures are for example speed limits, but also, considered long-dated, planning aspects. There must be an adequate distance between streets with a lot of traffic and new building projects (especially housing areas). In case of streets with more than 10 000 cars per day it is necessary in the region of Stuttgart to calculate diffusion of air pollution. Planning also should guarantee a good public traffic in case of new building areas.

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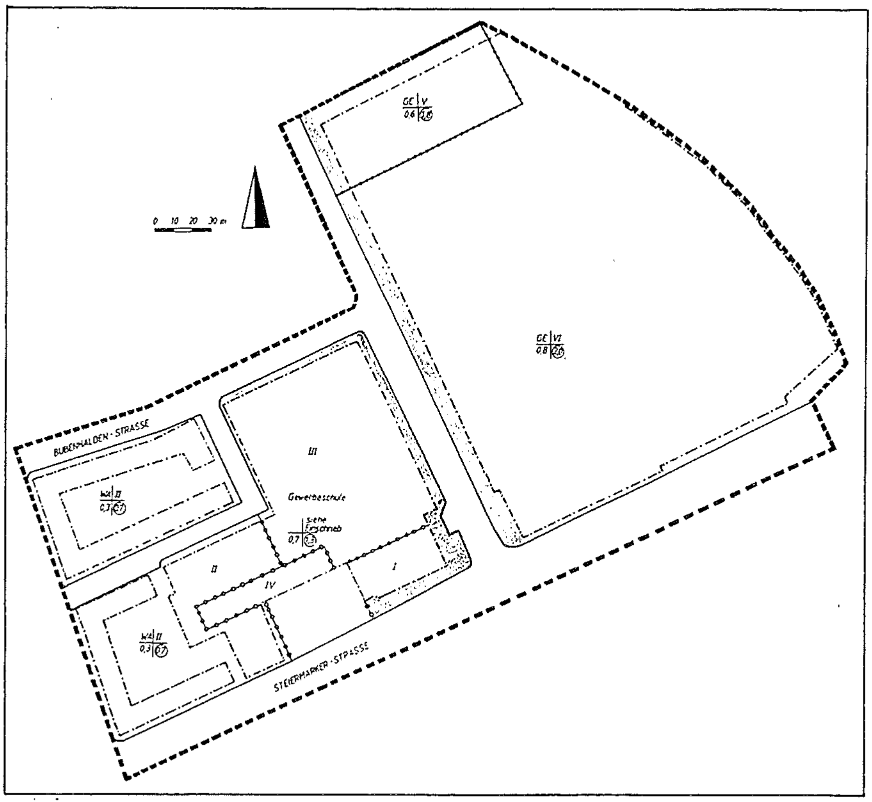

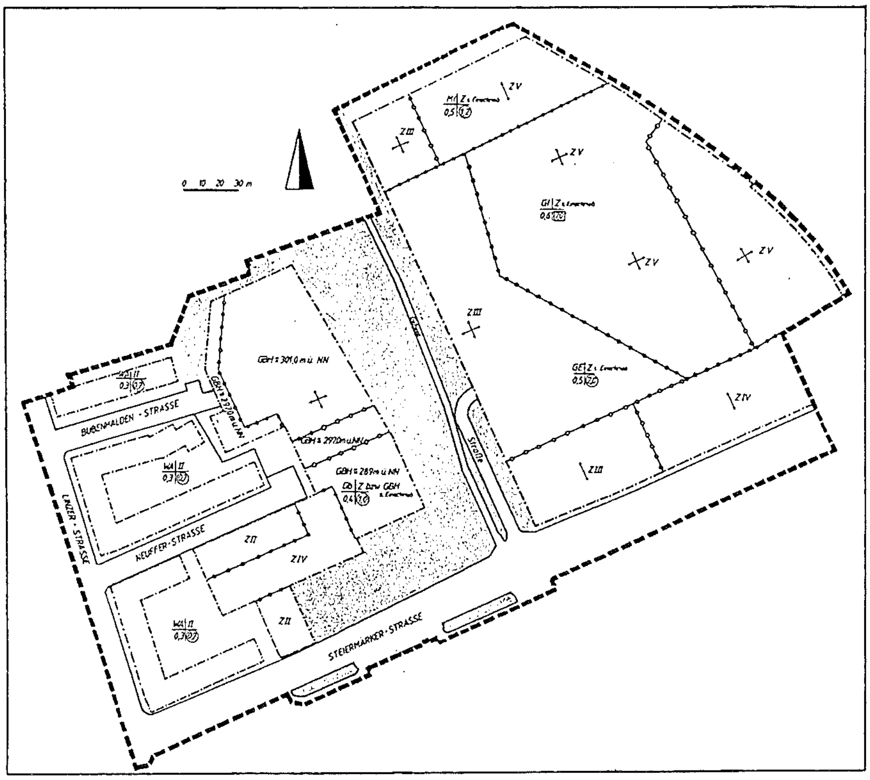

Figure 1: Zoning plan with original (top) green zone (gray) and improved zoning plan with the enlarged green zone for cold air flow (bottom)

NUMERICAL SIMULATION OF THE ENERGY BUDGET IN URBAN AREAS

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ABSTRACT

Over the last 10 years a mesoscale numerical model has been developed at the University of Karlsruhe and the Research Center Karlsruhe.

This model includes the effects of the terrain on the airflow by a terrain following coordinate system and is especially designed for the dynamical and thermal interaction between the earth surface and the atmosphere over complex terrain. In this paper an application of the model for the mesoscale surrounding and for the city of Karlsruhe itself is presented.

1. INTRODUCTION

Urban areas may be considered as those parts of the world where man has produced the strongest changes to the natural environment. From a meteorological point of view cities may be addressed (a) as zones of increased roughness, (b) as zones with large changes in the surface heat balance and (c) as zones with reduced evaporation or as zones with large changes in the mass budgets (Fiedler 1979).

Since the decisions made with respect to the development of cities have consequences for very long time periods, i.e. for decades, or hundreds or even thousands of years, one would expect that every aspect of the changes on the environmental conditions should be checked in different directions very carefully. However, in the normal procedure of the growth of cities and of industrial areas one is dealing with creeping processes and therefore they are not perceived as very dramatic processes during the life time of a person. The changes are much better visible by integrating the individual changes from year to year over a longer period, e.g. for hundred years. From the differences of the state at those time spans a quantitative conclusion can be drawn more easily. In natural conditions those exercises can document only what has already happened in the past and alternatives are not possible to study. In this respect numerical simulation models are the adequate tools which should be used extensively to assist long term plannings of city complexes and industrialized regions. With the respect to the area of Karlsruhe and its surrounding conditions in the Rhine valley a reasonable question should be: What condensation of living conditions with respect to settlements and the growth of industrialized zones is affordable in the Rhine valley or which condensation are we heading at if we proceed with the present changes and do we want to have the integrated effect in hundred years?

In the following short paper an application of the Karlsruhe Atmospheric Mesoscale Model (KAMM) is presented. Some results of the windflow are shown for the area characterized by complex terrain conditions.

2. MODEL APPLICATION AND RESULTS

The KAMM - model is a non-hydrostatic atmospheric model which takes into account the natural landscape by using a terrain following coordinate system and by taking into account different roughness, thermal conductivity, moisture content, soil type, vegetation type etc. within the different numerical grids.

The horizontal resolution is normally chosen between 500 m and 5 km. For the vertical coordinate a higher resolution is selected close to the ground with grid heights of 10 m to 20 m, which are transformed to a coarser resolution towards the top of the model domain with grid heights of 200 m to 400 m. The model domain covers several kilometers in the vertical (5 to 8 km) and in the horizontal directions from 15 km to several hundred kilometers, depending on the chosen grid size.

A description of the model may be found in Adrian and Fiedler (1991) or in Fiedler (1993).

The model needs as input a large number of parameter fields. In Fig. 1 the land use data for the area of Karlsruhe is shown. These data are derived from satellite measurement. From those data a transfer to physical parameters, e.g. aerodynamic roughness or albedo and several others is performed.

The horizontal distribution of the roughness length in a coarser grid consistent with the resolution of the model is shown in Fig. 2. With respect to the chosen area it is clearly visible, that some parameters like landuse indicate large horizontal differences, with respect to aerodynamic roughness there is only a small difference to the surrounding conditions. The effects of the city on the wind patterns will therefore not be so dramatic as can be found from several other published results for other cities. The mesoscale flow at 25 m above ground connected to a purely westerly synoptic wind is found in Fig. 3. The city of Karlsruhe which is located at the northern edge of the Black Forest is still occupied from the southerly channeled flow of the Rhine valley. Almost all large scale westerly directions of the synoptic wind are at low levels condensed to southerly flow directions. In reverse, with easterly synoptic flow conditions the surface wind flow shows a turn of 180° and flips to northerly directions.

Concerning the influence of the surface heat budget of the land surface a different situation may be expected. Observations of the temperature in a few meters above the surface at hot summer days show an increase of about 2 - 3 °C beyond the temperature level in the surrounding areas of Karlsruhe. The application of the KAMM - model on a summer day situation (see Fig. 4) shows for the 18 m level above ground (roof level of the city) at 15.00 hours an increase of about 1 - 2 °C within the city. However, it is visible, that changes in terrain height have a larger influence on the temperature than the different land use of areas with the same heights above sea level.

In many situations it is not an easy task to explain why a specific region shows a higher temperature in the Rhine valley than others. There are long distance effects of the mountains through wind shading, diminishing for example evaporation. In other zones precipitation is enhanced through vertical motions, triggered by the orography, and in still others the water storage conditions of the soil type is the dominating factor.

3. FUTURE WORK

Numerical models are the only tools, which allow systematic tests of the effect of different influencing factors. Detailed tests by applying the model KAMM will be performed for the whole Rhine valley on the effects of the forseeable changes of land use of the next hundred years in order to guide the decision makers in regional planning. Refinements will be produced especially for the larger cities in order to take into consideration local or regional meteorological regimes which are favorable for a pleasant climate in a changing world with a rapid growth of the population and a shortage of energy.

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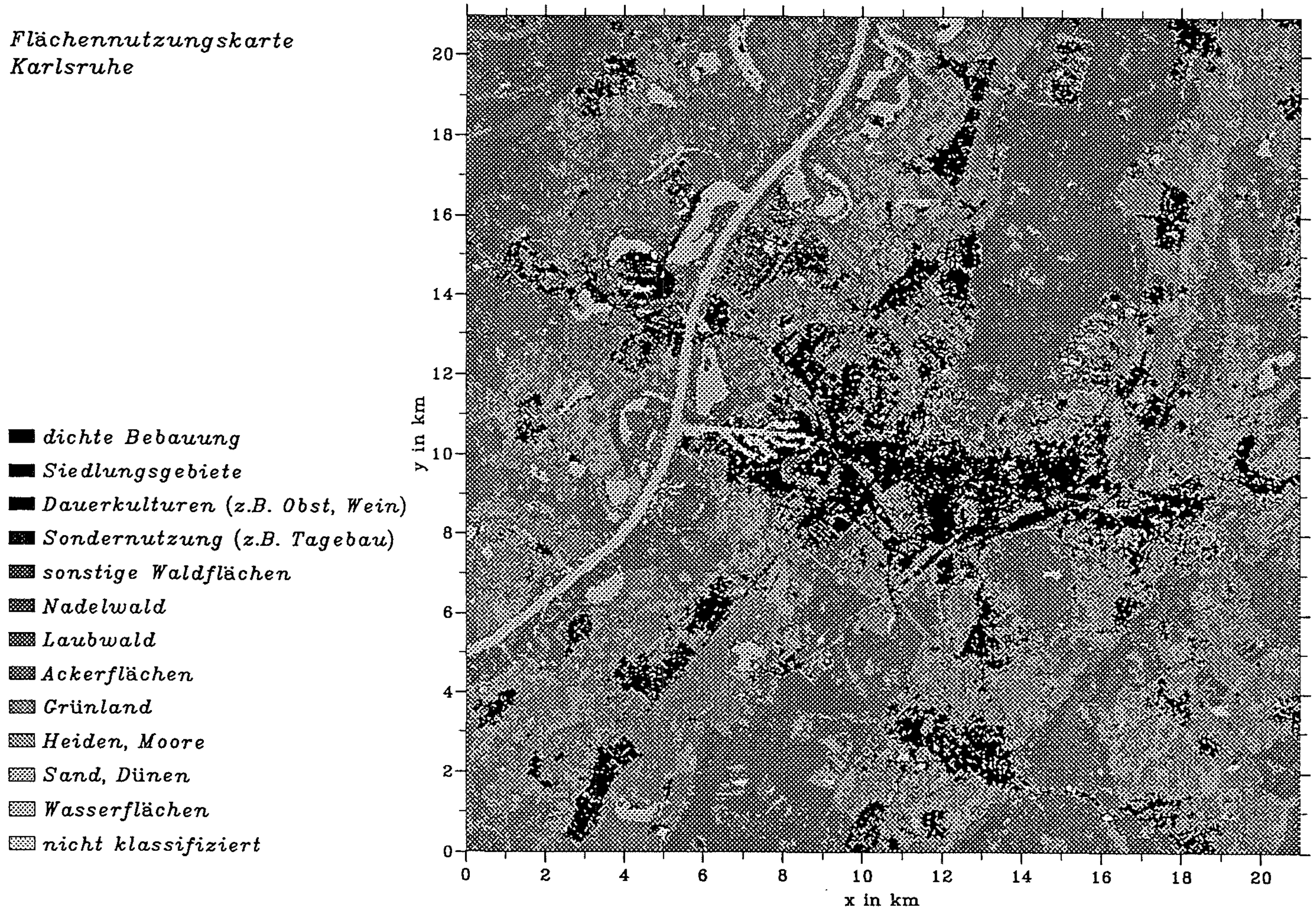

Fig. 1: The city of Karlsruhe represented by land use classification derived from satellite data.

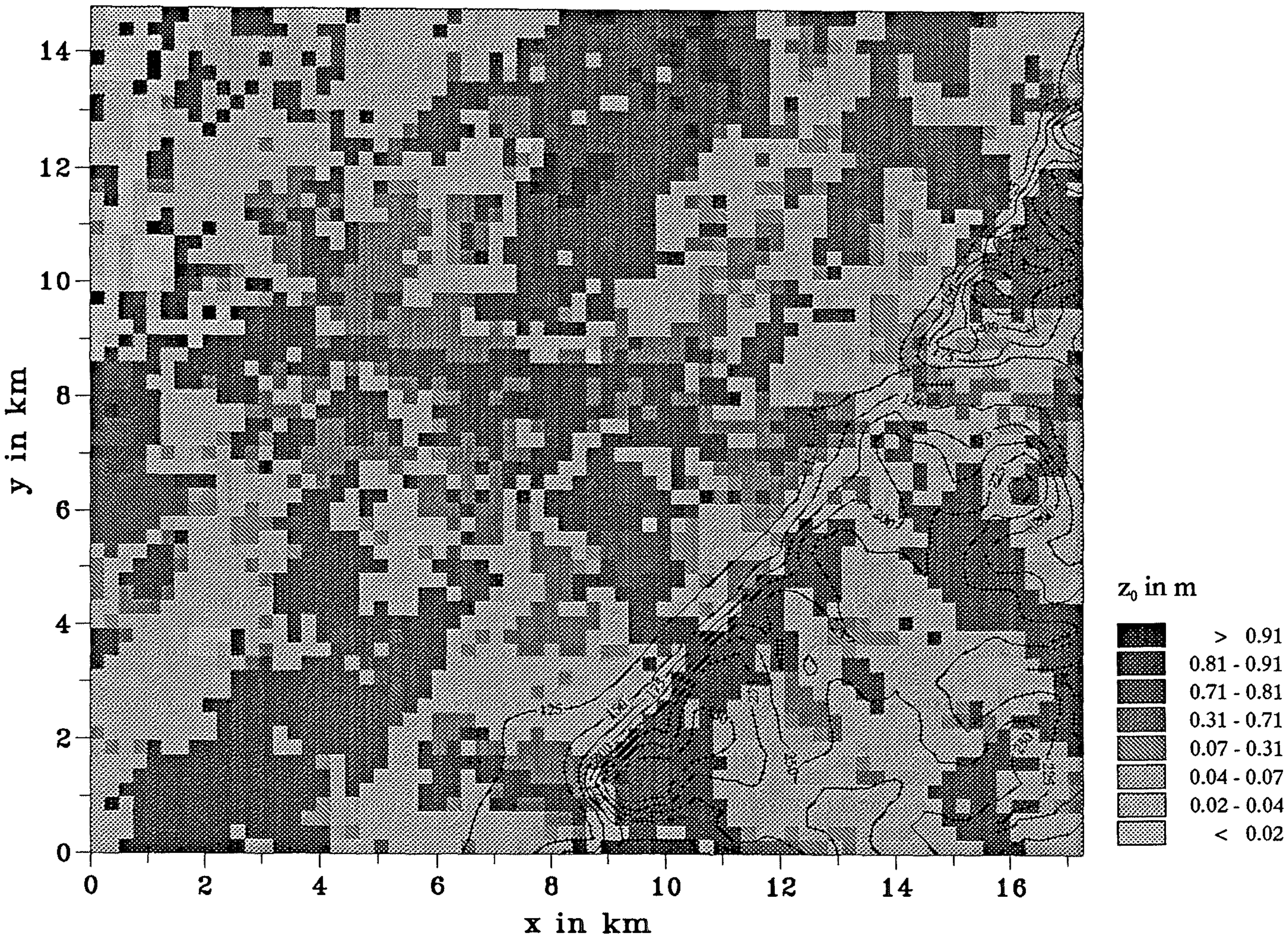

Fig. 2: Roughness length for the model domain derived from land use data.

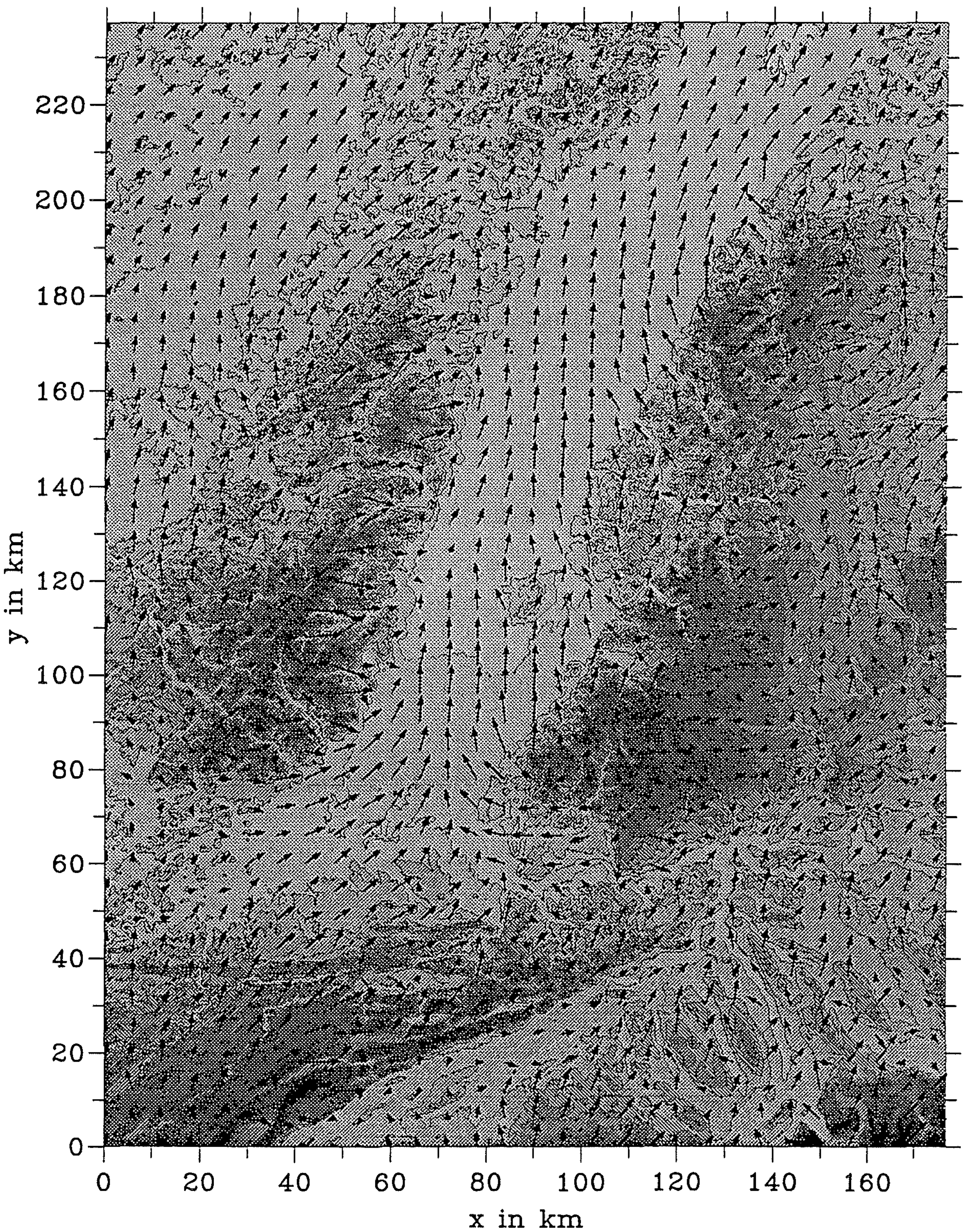

Fig. 3: Wind field at 25 m above ground within the Rhine valley and surrounding areas for a westerly synoptical flow.

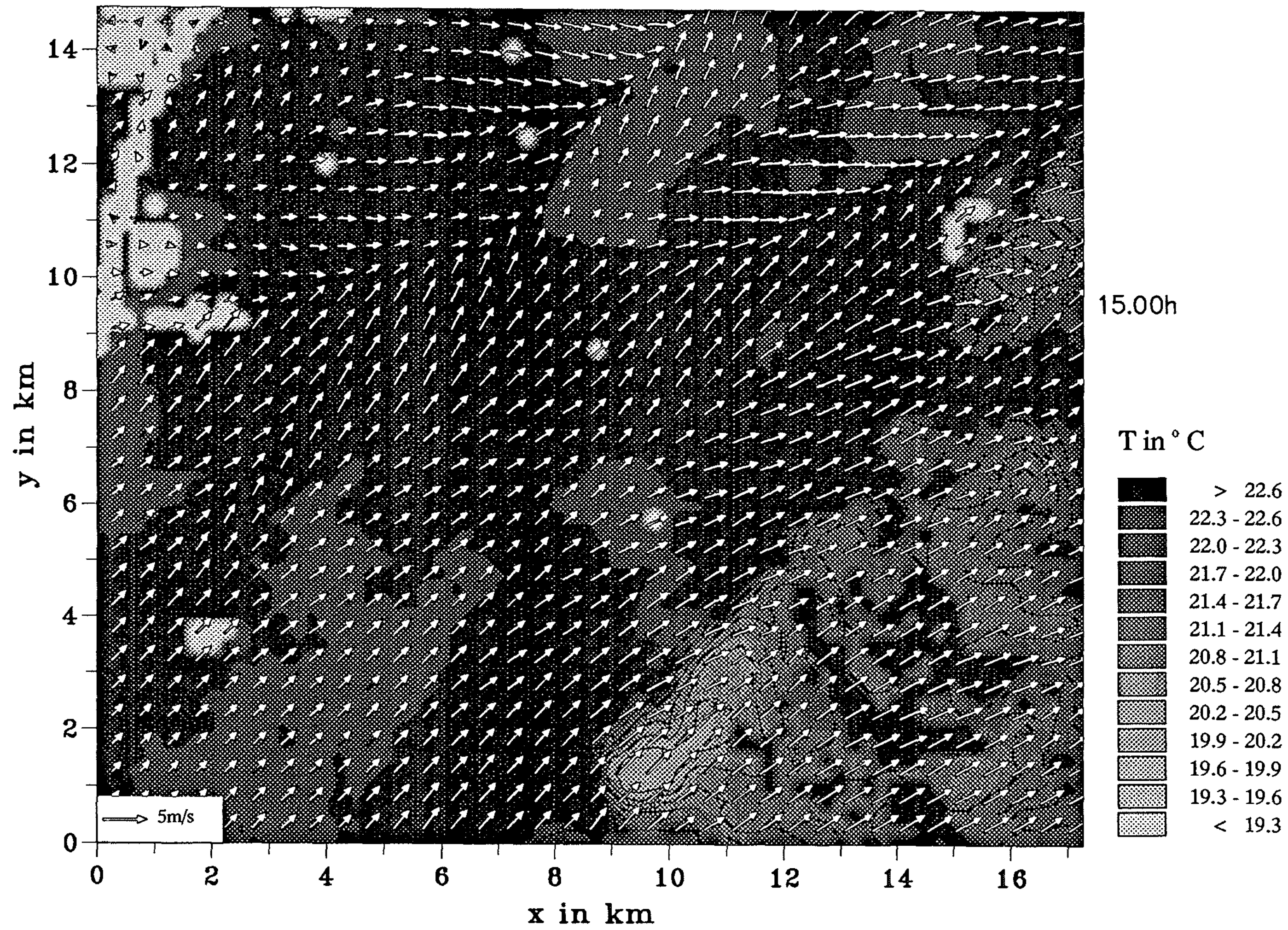

Fig. 4: The wind flow and air temperature at 18 m above ground at 15:00 CET derived from model simulations taking into account the energetic interaction between the soil/vegetation and the atmosphere.

EVALUATION OF VENTILATION RATE IN BUILT-UP AREA USING CONVECTIVE TRANSFER COEFFICIENT

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ABSTRACT

In this paper, measuring evaporation rate from the filter paper pasted on building model surface, convective mass transfer coefficient (*k*) at outside surface was examined by wind tunnel experiments. Because (*k*) is closely related to air flow near the building surface, it is possible to estimate ventilation rate of urban street canyon from the distribution of it. This time, (*k*) of several kinds of city block with different building arrangement were examined, and some well-ventilated city design were proposed.

1. INTRODUCTION

Effective land-use is, of course, one of the important policy in an urban area everywhere. In Japan, because of the steep rise in land-price, many building sites were broken into small pieces, and slender pencil-like buildings were standing without enough space between surrounding neighbors. In these built-up area, environment near the ground is far from comfort. The stagnation of air mass with low wind velocity leads severe air pollution by the motor-traffic emission and also creates unbearable thermal environment for the pedestrians in summer.

The purpose of this paper is to clarify the criteria of street canyon geometry or density of buildings for the desirable healthy ventilation rate. According to the real scale measurements about convective transfer coefficient at outside building surface, it was closely related to the air flow near the building. Therefore, this time we tried to evaluate ventilation rate in built-up area using the convective transfer coefficient in wind tunnel model experiments.

2. MEASURING TECHNIQUES

By the measuring of evaporation rate from the filter paper pasted on building model surface, the convective mass transfer coefficient at outside surface was examined (Figure 1). The filter paper used in measurements was 1 mm thick, and its side surfaces were treated by waterproofing agent. A very fine thermistor sensor was inserted from the side surface just below the paper surface to measure evaporating surface temperature. The weight loss for a half hour (about 200 - 400 mg) was measured by electric balance (the accuracy was 0.1 mg).

Then, the convective mass transfer coefficient (k) was calculated by

$$k = E / (e_s - e_a)$$

where E is evaporation rate, e_s is saturated vapor pressure of evaporating surface temperature, and e_a is vapor pressure of approach flow.

The dimensions of wind tunnel outlet are 900 mm in height and 1800 mm in width. By means of several kinds of roughness elements between outlet and working section, vertical profile of mean velocity was fitting to power law of 1/4 and turbulence intensity at roof level of the typical building model was set to 20 %.

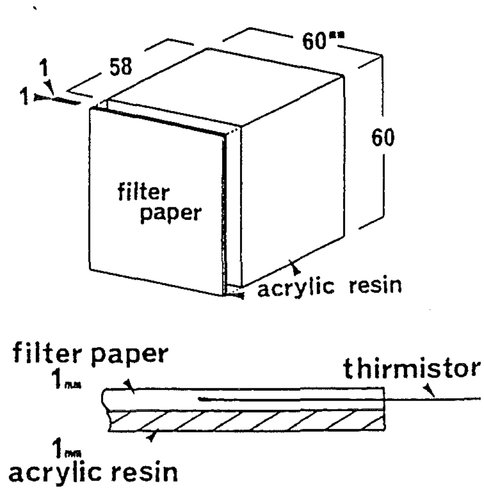

Figure 1. Building model

3. FULL SCALE OBSERVATIONS

It is necessary to describe some results of our full scale observations before going into the main subject in wind tunnel experiments. The real scale measurements of (k) were conducted at the window facing north on the seventh floor of eight-story building. The same filter paper (710 x 710 mm) was pasted on the windowpane surface and moistened overall. Measuring the weight loss of its center part piece (60 x 60 mm) by evaporation, (k) was calculated in the same manner. The relations between convective transfer coefficient (k) and wind velocity were determined in the different sites within the same floor, for example center part or edge, with balcony or not, and so on. In these observations, fine wind structures near the window were also measured with three dimensional ultrasonic anemometer (5 cm span).

Figure 2 shows the example of relations between (k) and the 30-minute means of wind speed at 15 m above the roof. These relations change due to the upper stream direction, that is, in the case of windward or leeward surface. On the other hand, (k) has the linear relation to the mean wind in the vicinity of the window regardless of the upper stream direction (Figure 3).

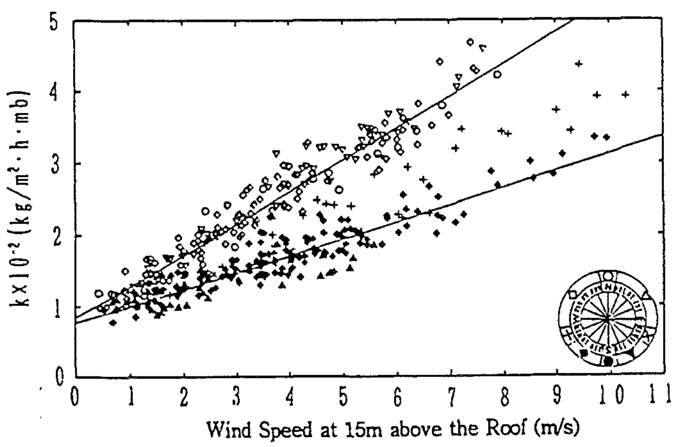

Figure 2. Relations between convective transfer coefficient and wind speed above the roof.

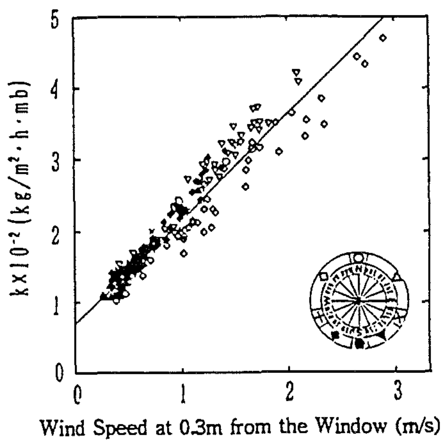

Figure 3. Relations between convective transfer coefficient and wind speed near the window.

This result suggests that it is possible to estimate ventilation rate of urban street canyon from the distribution of convective transfer coefficient.

4. WIND TUNNEL EXPERIMENTS

The relations between (*k*) of two dimensional urban canyon and canyon geometry are shown in Figure 4. In this figure, (*k*) is standardized by that of horizontal plate (k_o) which has same dimension as the model surface and located near the outlet. These values are the average of three measurements at the wind speed of free stream **U** = 2, 4 and 6 (m/s). In the range between **L/H** = 1 and 2.5, which corresponds to the flow pattern of wake interference, the value (*k*) of windward is decreased while that of leeward is increased. These values of windward and leeward decrease rapidly in the range of **L/H** < 1 (skimming flow pattern), then converge same value in the end. On the contrary, the value (*k*) of roof surface is almost constant within the limit of this experiment.

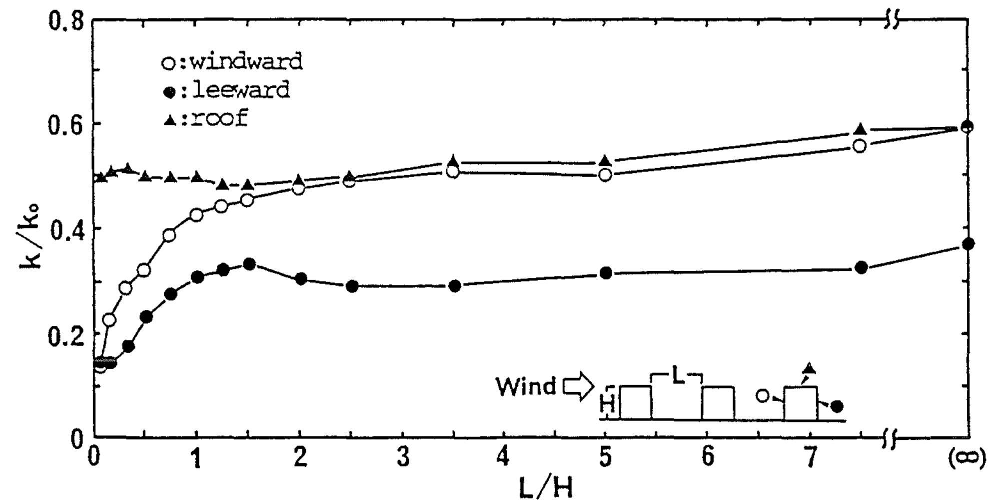

Figure 4. Change of convective transfer coefficient of two dimensional urban canyon due to canyon geometry.

Figure 5 shows the perspectives of city block model tested as a case study of ventilation rate. 5 x 5 of cubic models are set with interval 1/6 of model height. Though it is omitted in the figure, sampling was carried out in the half part of center block in the 3 x 3 of block arrangement. The street width between each block is equal to the height of cubic model. Here, the effect of open space **(type-B)** and the effect of building shape change under the condition that rate of building volume to lot is constant **(type-C)** were investigated in comparison with standard arrangement **(type-A)**.

The distributions of (k) in **type-A** are shown in Figure 6. Because each path forms relatively narrow and deep street canyon within the inside of blocks, the value (*k*) of vertical surface (●O▲) are only 40 to 50 % as compared with that of roos surface (◆). Within the block, the (*k*) of vertical surfaces tend to decrease slightly toward the center of it. In this area, the difference of (*k*) due to the surface direction against the wind is not so obvious. As for the peripheral surfaces facing the wide street (Δ) the (*k*) of these surfaces amount to about one and a half times as that of inside area.

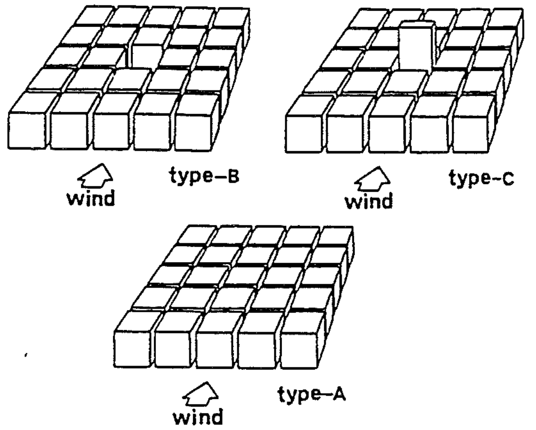

Figure 5. Perspectives of city block model.

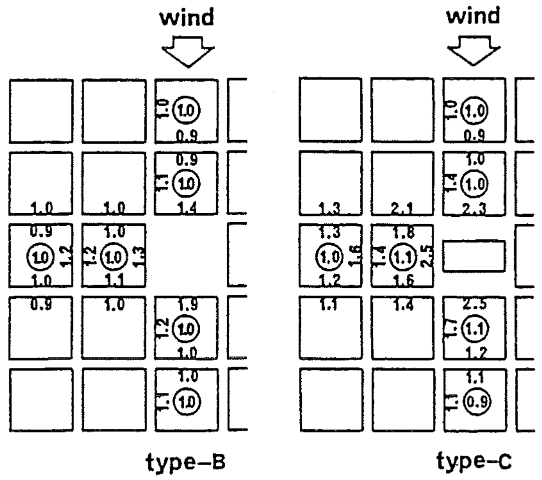

Figure 7. Ratio of convective transfer coefficient in type–B and type–C to that of type–A.

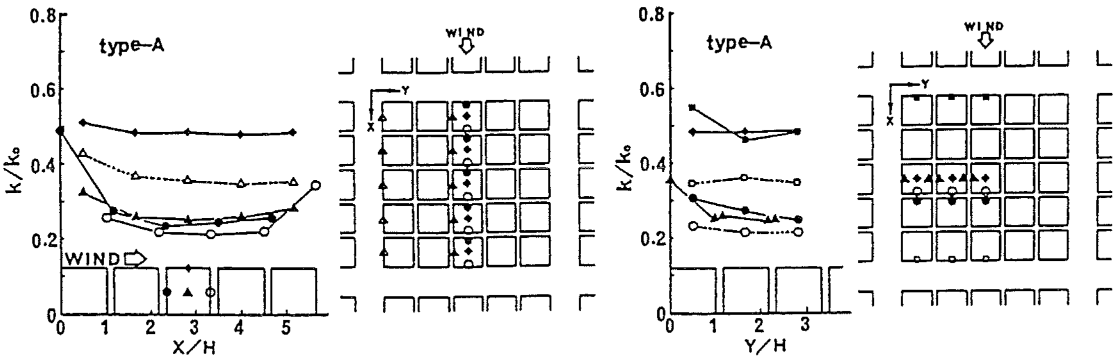

Figure 6. Distribution of convective transfer coefficient in type–A model.

Finally, figure 7 is the results of case study, expressed by the changing ratio of convective transfer coefficient. The numbers within the circle mean the value of roof surfaces, and the others do that of vertical surfaces. In the case of **type-B**, large increment of (k) is restricted within the vertical surfaces facing open space in question. On the other hand, in **type-C**, (k) is increased remarkably not only around high-rise building created but also the inside streets beyond the low-rise cubic models surrounded.

5. CONCLUSION

In this paper, we proposed the new technique to evaluate ventilation rate using convective transfer coefficient. Generally, wind velocity has a strong locality in its distribution, particularly in built-up area. Therefore, even if a very fine hot wire is used as a sensor, it is not so easy to know the space-averaging wind velocity within a street canyon. In this experiments, it is possible to evaluate the ventilation rate of whole street-space without difficulty, and also there is no disturbance by any kinds of sensor in air flow during the measurements. These are advantage of this technique and it is considered to be quite a convenient method for short-time investigations on the spatial distribution of wind environment in city planning.

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FIELD STUDY ON THERMAL ENVIRONMENTS IN SOME TYPES OF URBAN BLOCKS

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ABSTRACT

Field measurements were performed on the thermal environments in three types of urban blocks in Osaka in the summer season. The air temperatures in the daytime depended on the types of urban blocks. They were affected by the sensible heat transfer from the road and the wind speed. In the nighttime, there was a small difference in temperatures among the urban blocks, which were higher than those in the green park.

INTRODUCTION

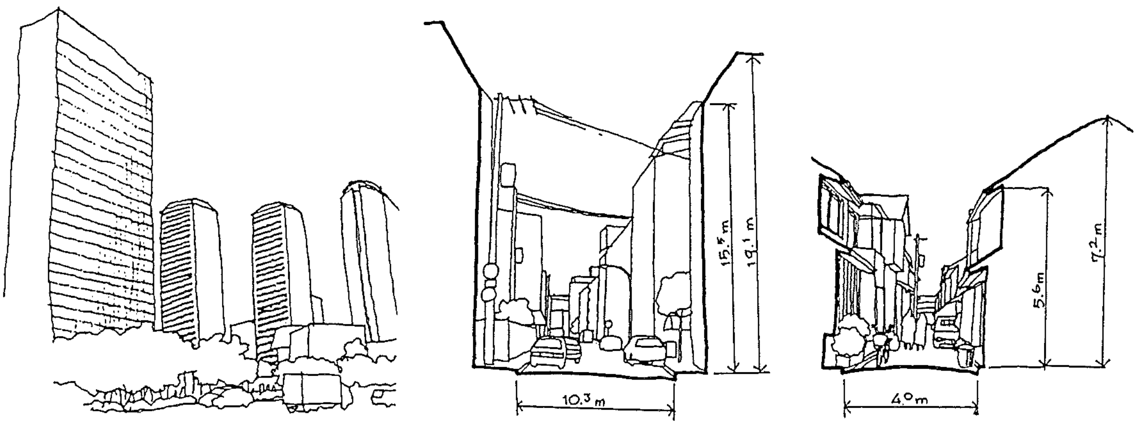
In order to create the comfortable life condition, it is necessary to make clear the effects of the urban block type such as the building height and the building-to-land ratio on the thermal environments in an urban block scale. The results obtained are connected with the improvement of the thermal environments in the whole urban area. One of the authors has studied the heat transfer in a building canyon as a basic unit of urban block by using the data of field measurements [1].

In the present study, simultaneous field measurements are performed on the thermal elements in three different types of urban blocks in Osaka in the summer season. The mechanism of the thermal environments is investigated based on the measured data.

MEASUREMENT SITE AND METHOD

The measurement sites were three types of urban blocks shown in Fig.1 and Table 1, which were Osaka Business Park [O-site], Tenmabashi Area [T-site] and Kyobashi-Shigino Area [K-site]. These urban blocks were located less than 1.5 km from Osaka Castle Park [P-site] as the reference site.

The measurement period was July 28-31 in 1993. Before 5 a.m. on July 30, the moving measurements were simultaneously performed in the urban sites three times a day. The starting times of the measurements were 5 a.m., 1 p.m. and 8 p.m.. After then, the same measurements were performed at intervals of 2 or 3 hours. The continuous measurements were performed in the green park [P-site]. In each urban site, four measurement points were positioned in the center of the neighboring building canyons in consideration of the canyon direction. The first and last measurements were performed in the same point. A series of measurement took about 30 minutes.



(a) O-site (b) T-site (c) K-site

Figure 1 Sketch of measurement sites of urban blocks

Table 1 Statistical data for measurement sites of urban blocks in 1990 (* 1986)

Measurement Site	Osaka Business Park (O-site)	Tenmabashi (T-site)	Kyobashi-Shigino (K-site)
population density [person/km^2]	0.0	1.40×10^4	2.15×10^4
building to land ratio [%]	59*	54	78
floor area ratio [%]	457*	305	158
average number of stories [%]	-	5.6	2.0
average width of streets [m]	28.6	10.3	4.0
building structure	steel	reinforced concrete	wood
zone	commercial	residential & commercial	residential

The measured items in the urban blocks were the air temperature, the relative humidity, the wind speed and the surface temperature. The measured height was 1.2 m and the averaged values for 1 minute were recorded except for the surface temperature. The air temperature and the relative humidity were measured by the resistant sensor made of platinum and the polymer film inserted in the radiation shielded cylinder with forced ventilation, respectively. The wind speed was measured by three-cup anemometers. The surface temperatures were measured by infra-red radiation thermometers at several positions for each measurement point in consideration of the materials and solar radiation. The continuous measurements of the air temperatures were performed at the height of 30 m above the roof of building in T-site and at the height of 10 and 1.5 m in P-site where the green canopy spread horizontally between 6 and 11 m in height. The measurement instruments were compared each other and were calibrated.

Figure 2 shows the meteorological condition measured by Osaka meteorological observatory. The characters of T, f, S and R indicate the air temperature, the relative humidity, the solar radiation and the rainfall, respectively. The symbol of o means the rainfall less than 0.5 mm. It was almost fine weather in the measurement period except for July 30.

RESULTS AND DISCUSSION

Figure 3 shows the air temperatures T of four points in T-site. The difference among the points is slightly observed in the daytime. There is no significant difference in the nighttime.

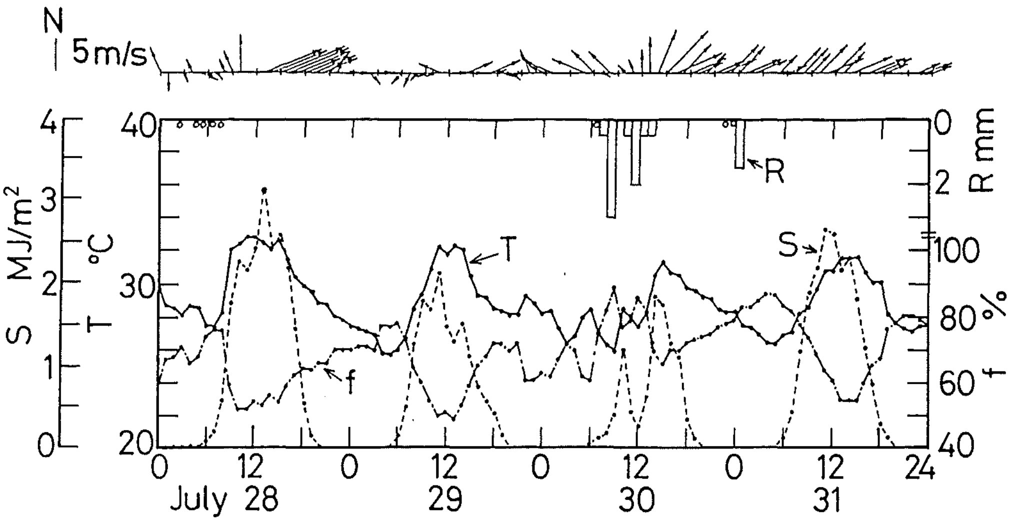


Figure 2 Meteorological conditions

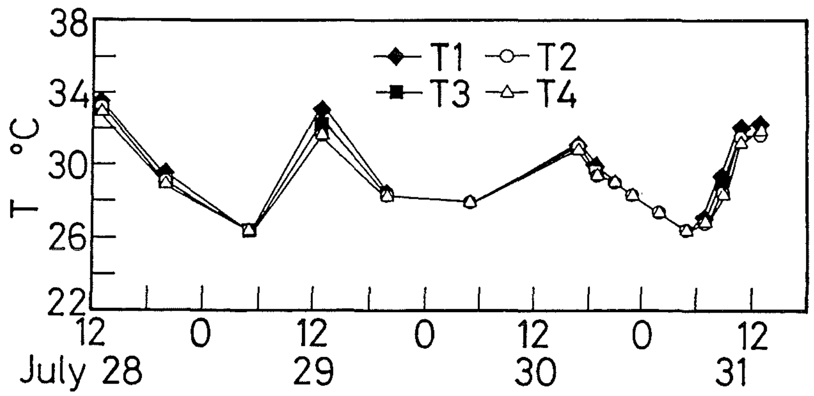


Figure 3 Air temperatures in T-site

As the same tendency is also recognized in other sites, the averaged air temperature among the measurement points is regarded as the air temperature in each site.

Figure 4 shows the air temperature differences ΔT between the urban sites and the green park [P-site] at 1.5 m in height. The air temperatures in urban sites are always higher than those in the green park. The air temperature differences among the urban sites are large in the daytime and small in the nighttime. The air temperatures become low in the order of K-site, T-site and O-site. There is a small difference in ΔT in K-site between the daytime and the nighttime except for the time zone in which the measured data are affected by rainfall. The values of ΔT in the nighttime in O-site are larger than those in the daytime. The intermediate tendency is observed in T-site. The air temperature rise in O-site, where the road width and the open area are large, decreases in the daytime owing to the ventilation shown in Fig. 5. In the nighttime, the air temperature fall in the urban sites is prevented and there is a small difference in air temperatures among the different types of urban block owing to the heat release from the artificial cover according to the amount of the heat storage in the daytime.

Figure 5 shows the average relative humidity f and the wind speed V of the measurement points. There is no significant difference in relative humidity. The wind speed in O-site is larger than that in other sites, especially in the fine daytime.

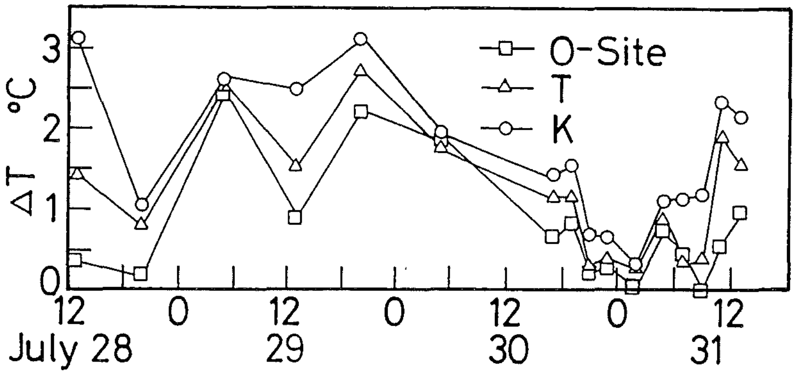


Figure 4 Air temperature differences between the urban sites and P-site (green park)

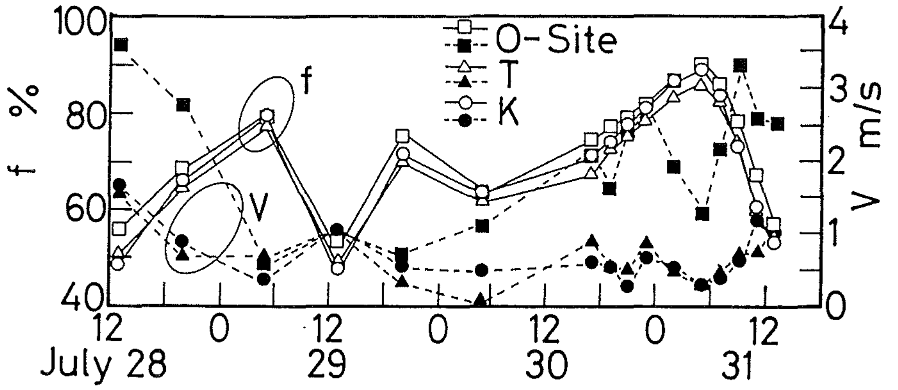


Figure 5 Relative humidity and wind speed in urban sites

Figure 6 shows the differences between the average surface temperature and the air temperature in each site, ΔT_s . The surface temperatures are measured on the sunny asphalt pavements and the concrete walls with a southern exposure in the east-west oriented canyon. The surface temperatures are always higher than the air temperatures. Even in the nighttime, the heat is released from the surface into the surrounding air. The surface temperatures on the roads are higher than those on the walls, especially in the daytime. The air temperatures are much dominated by the sensible heat transfer from the road surface even in consideration of the surface area of the road and the wall. In O-site, the difference of surface temperature on the road between daytime and nighttime is larger than that in other sites, because the sky view factor from the road is largest. Compared with T-site and K-site, the values of ΔT_s in road in K-site are larger than those in T-site because of the aspect ratio.

Figure 7 shows the air temperatures at the roof level and near the ground. In this figure, P_r and P_c indicate the air temperatures at 10 and 1.5 m in height in the green park [P-site], respectively. T_r and T_c indicate the air temperatures at 30 and 1.2 m in height in T-site, respectively. The data of T_c are the results of the moving measurements. The vertical air temperature difference is not observed in T-site except for July 31. This result shows the thermal diffusion is active in urban blocks. The air temperatures at the sunny top of the green canopy are higher than those near the ground in the calm morning. The air temperatures at the roof level in T-site are higher than those in P-site in the same manner as those near the ground. The difference becomes large from the evening to the early morning.

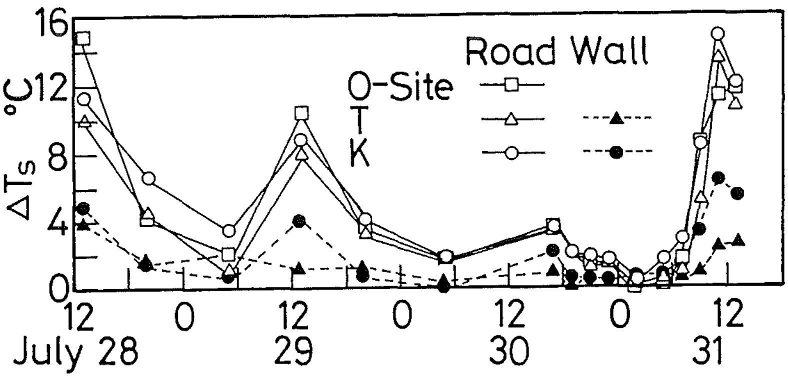


Figure 6 Differences between the surface temperature and the air temperature in urban sites

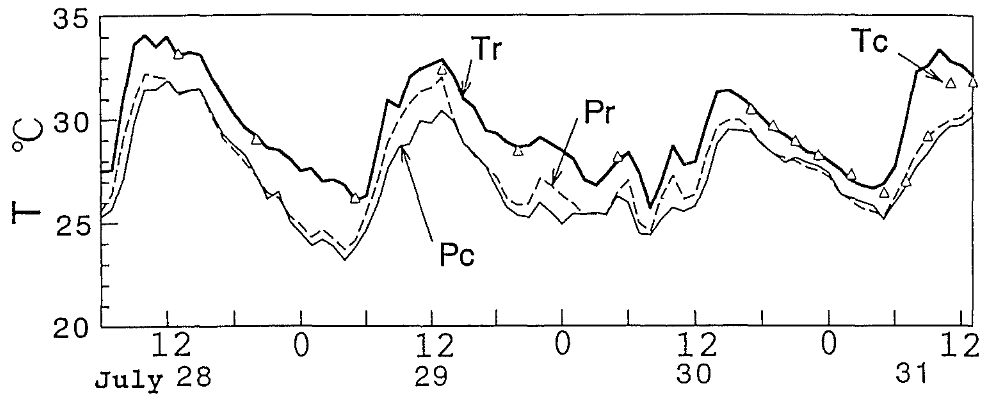


Figure 7 Air temperatures at the roof level and near the ground in T-site and P-site (green park)

SUMMARY

(1) The air temperatures in the urban blocks were always higher than those in the green park.

(2) The air temperatures in the daytime depended on the types of urban blocks.

(3) The air temperatures in the urban blocks were strongly affected by the sensible heat transfer from the road and the wind speed.

(4) The air temperatures in the urban blocks were equal to those above the roof of the buildings.

ACKNOWLEDGEMENT

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THE VARIATION OF MEAN FLOW AND TURBULENCE OVER A SMALL ESCARPMENT

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ABSTRACT

This presentation will show how a 16 m high escarpment will influence the atmospheric flow and thus the local wind climate. Measurements of mean flow and of turbulence over this escarpment will be presented for various atmospheric stabilities. The speed-up in the mean wind field shows the known increase with increasing atmospheric stability. Cross sections of the standard deviation of horizontal and vertical wind components and of the friction velocity are presented. It becomes obvious that the increase of turbulence in the wake is most sensitive to the thermal stratification of the flow.

INTRODUCTION

Atmospheric flow in the planetary boundary layer is decisively determined by the mechanical and thermal properties of the underlying surface. For a horizontally homogeneous surface and neutral atmospheric stability we find the well-known logarithmic wind profile in the Prandtl-layer and a linear wind profile in the surface layer below which is dominated by molecular viscosity (see Fig. 1).

Buildings will disturb this idealized feature. And often buildings and towns are erected in areas where orographic structures exist. These structures will also alter the vertical profiles of wind and turbulence and thus the local wind climate. Fig. 2 shows some principle surface inhomogeneities and their basic effect on the atmospheric flow. The presence of a gentle hill in a neutrally stratified flow is only felt close to the hill itself. Further downstream the undisturbed profiles are reestablished. The flow changes are somewhat different for a roughness change or a step or escarpment. Here a new internal boundary layer (IBL) forms downstream of the onset of the disturbance and the flow takes some time until a new equilibrium is established. The presentation will focus on the last type of these inhomogeneities.

Two possible examples for this feature could be 1) an orographic feature or 2) a large flat building. The first example may apply to the planning of buildings or the consideration of pedestrian comfort close to the upper edge of the escarpment. A location closely behind the upper edge might also be a suitable position for a wind mill. The second example may apply to the situation on top of larger flat buildings (e.g. car parks) which are accessible to the public.

OBSERVATIONS AND RESULTS

Wind tunnel experiments (BOWEN and LINDLEY 1977) have shown the variation of mean wind speed and turbulence for a cliff and for escarpments with various slopes for neutral atmospheric stability. Most prominent is the speed-up close to the upper edge and the enhanced turbulence in the wake of the structure. Here we will present some data from a field experiment for three different stability classes. The experiment was performed in autumn 1989 in Denmark together with Risoe National Laboratory. Further details of the design of the experiment can be found in EMEIS et al. (1993).

Figs. 3 and 4 show the relative speed-up of the mean wind speed over the escarpment and the standard deviation of the vertical wind component (normalized with the undisturbed value upstream) for unstable stratification (top), neutral stratification (middle), and stable stratification (below). We see the maximum speed-up is increasing with increasing stable stratification. The maximum speed-up in the wake further downstream is lifted from the ground for unstable and neutral stratification but is attached to the ground for stable stratification. The borderline between retarded and enhanced flow is moving up the slope for increasing stability and the retardation is strongly depending on the thermal state of the flow.

As an example for the turbulent quantities the standard deviation of the vertical velocity component is presented here. The enhancement of this component of turbulence over the slope is increasing with increasing stability but remains unchanged in its position. In contrast to this the features in the wake vary considerably with atmospheric stability. Further analyses of the turbulent quantities will be presented in EMEIS et al. (1994).

CONCLUSIONS

Steps and escarpments modify the vertical profiles of wind speed and turbulence. Partly these modifications strongly depend on the thermal state of the atmosphere. Enhancement of the wind speed on top of escarpments and enhancement of turbulence in the wake of such structures influence the maximum load on buildings there and changes the pedestrian comfort in these positions considerably. The measured data can also be used to verify numerical models which have been designed to model the flow over buildings and/or over complex orography.

ACKNOWLEDGEMENTS

Thanks are to be given to the groups which performed the measurements. The Danish group was led by Niels Otto Jensen, the German group by Franz Fiedler and Klaus Heldt. I am especially thankful to Helmut Frank who took part in the examination of the turbulence data. The German part of this experiment was financed by the *Deutsche Forschungsgemeinschaft* via the *Sonderforschungsbereich 210*.

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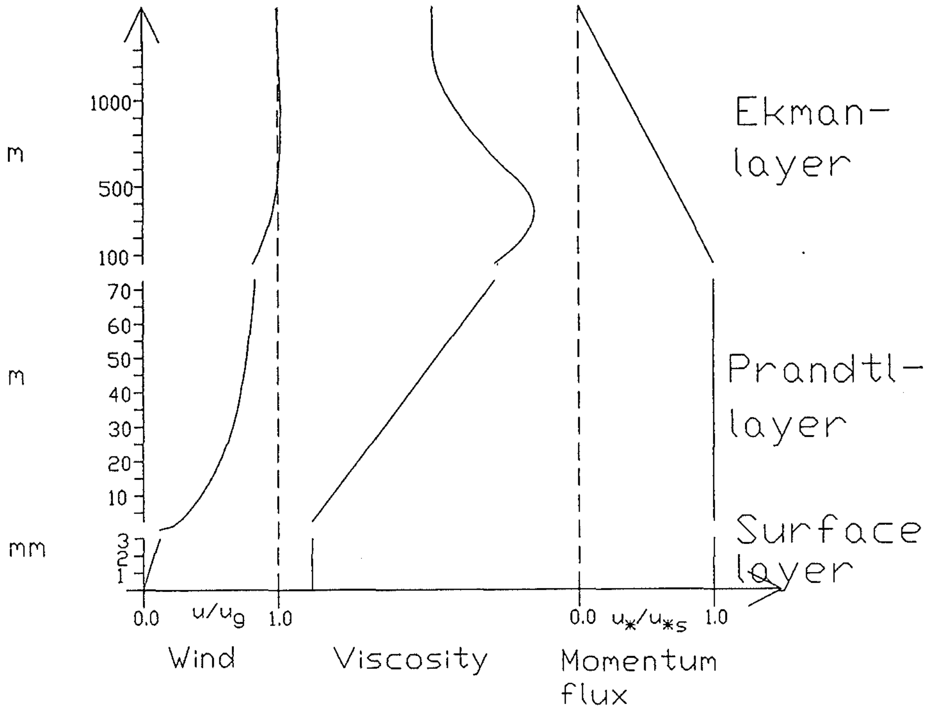

Figure 1. Vertical profiles of wind (left, normalized with geostrophic wind speed), viscosity (middle, arbitrary units), and momentum flux (right, normalized with surface flux) in the atmospheric boundary-layer. Note the different height scales in the three sub-layers of the boundary-layer.

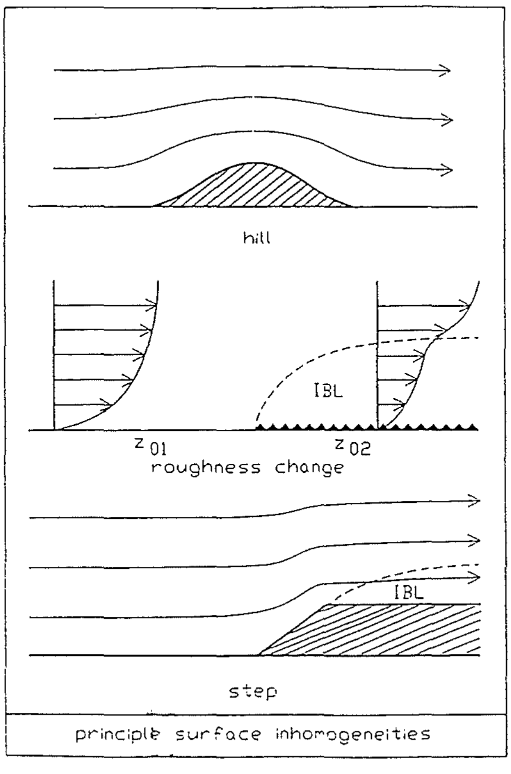

Figure 2. Influence of simple surface inhomogeneities on atmospheric flow.

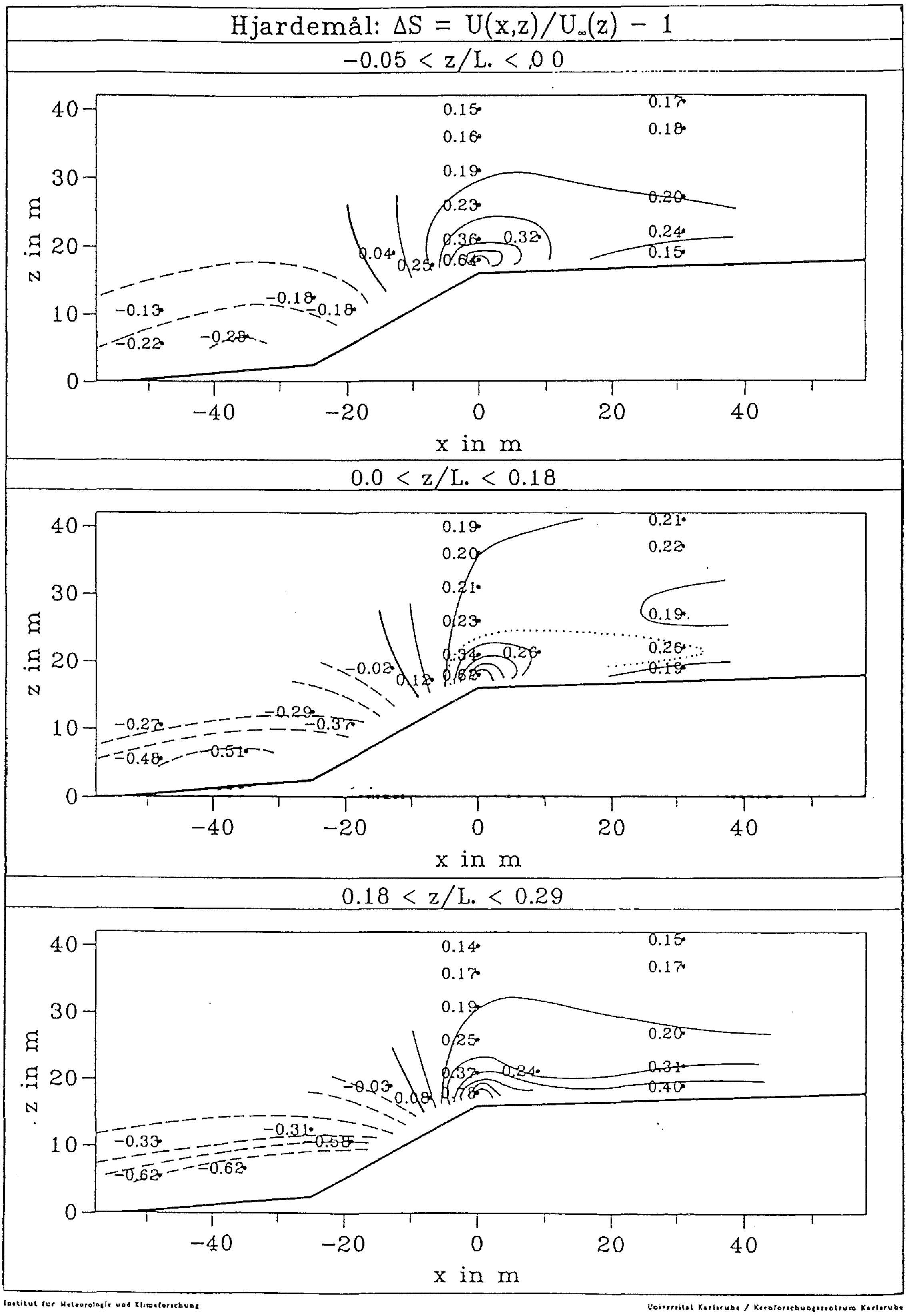

Figure 3. Relative speed-up of flow perpendicular to the escarpment for unstable (top), neutral (middle), and stable (below) atmospheric stratification.

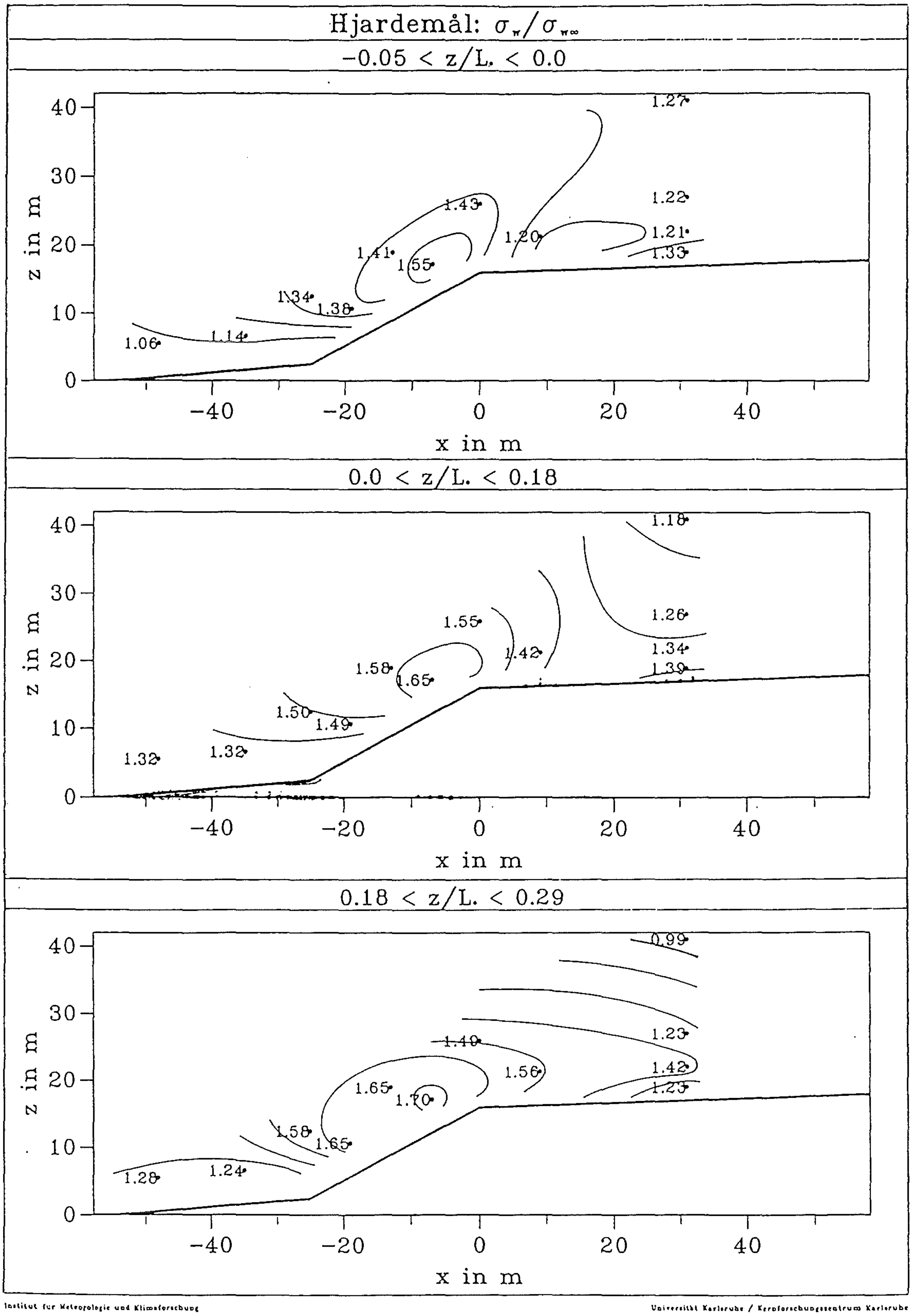

Figure 4. Standard deviation of vertical velocity component, normalized with upstream value, for unstable (top), neutral (middle), and stable (below) atmospheric stratification.

A PREDICTIVE MODEL OF URBAN CLIMATE FOR THE LAND UTILIZATION

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INTRODUCTION

The climate in the summer is hot and stuffy in Japan. What is worse, the air temperature in the cities getting higher because of the decrease of green area or the increase of artificial heat released. The land utilization planning is expected to be a major method to improve the thermal environment in the city. And it is necessary to predict urban climate quantitatively. An all-inclusive planning tool is proposed and discussed in this paper. The menu of building form or use, energy consumption, surface material is prepared for the land utilization planning and the numerical model which is able to estimate the air temperature at each land utilization is developed. Then, some case studies are set up and the way for the mitigation of urban climate is examined.

PARAMETER PREPARATION

The planning data of land utilization disposition should be modified to parameters for the numerical model to predict the micro climatic impact. Figure 1 shows how to modify the planning data for the predictive model. At first, the location and season of planning area should be given as fundamental data. The boundary condition for the predictive model will be supplied from the meteorological data base. Next, building use, building form, surface material, traffic quantity should be decided as the planning data. From these planning data, energy released, thermal property and roughness height will be estimated as parameters of the predictive model.

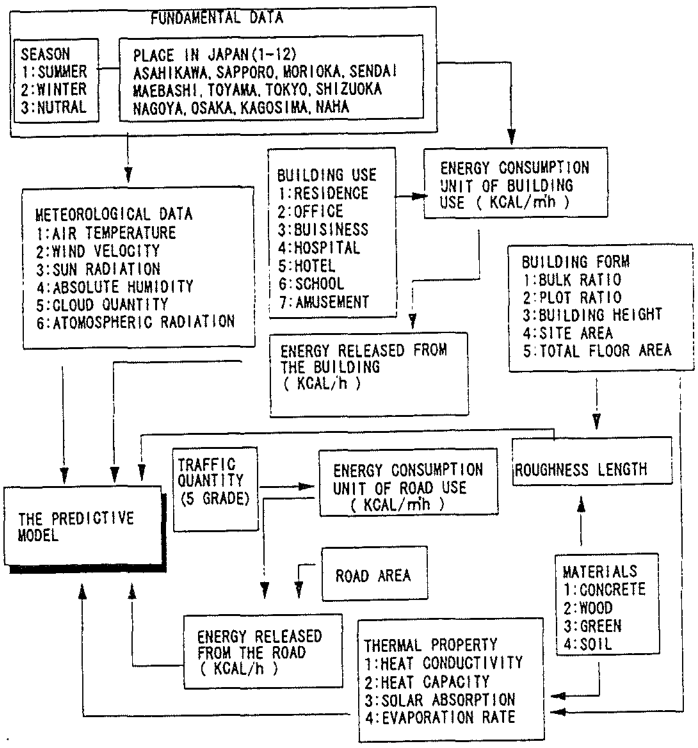

Figure 1 The data flow from the plan to the predictive model

THE PREDICTIVE MODEL

The constant flux layer model is adopted. The universal function which is based on the Monin-Obukhov's analogies is used to consider atmospheric stability (1). Moriyama estimated the average climate in the city using the average data of the land utilization (2).

It is noticed that the locality of the lands is getting vaguer as the measuring point is higher. Then, we suppose the analyzed zone is separated to two zones. The upper one which is from 10 m to 100 m height, is calculated on the assumption of the horizontal uniformity in the 500 m square. The lower one is from the roughness height to 10 m height and consists the meshes of 10 m square. They are calculated at each land utilization by the one dimensional way under the boundary condition at 10 m height. The calculation way is shown in Figure 2.

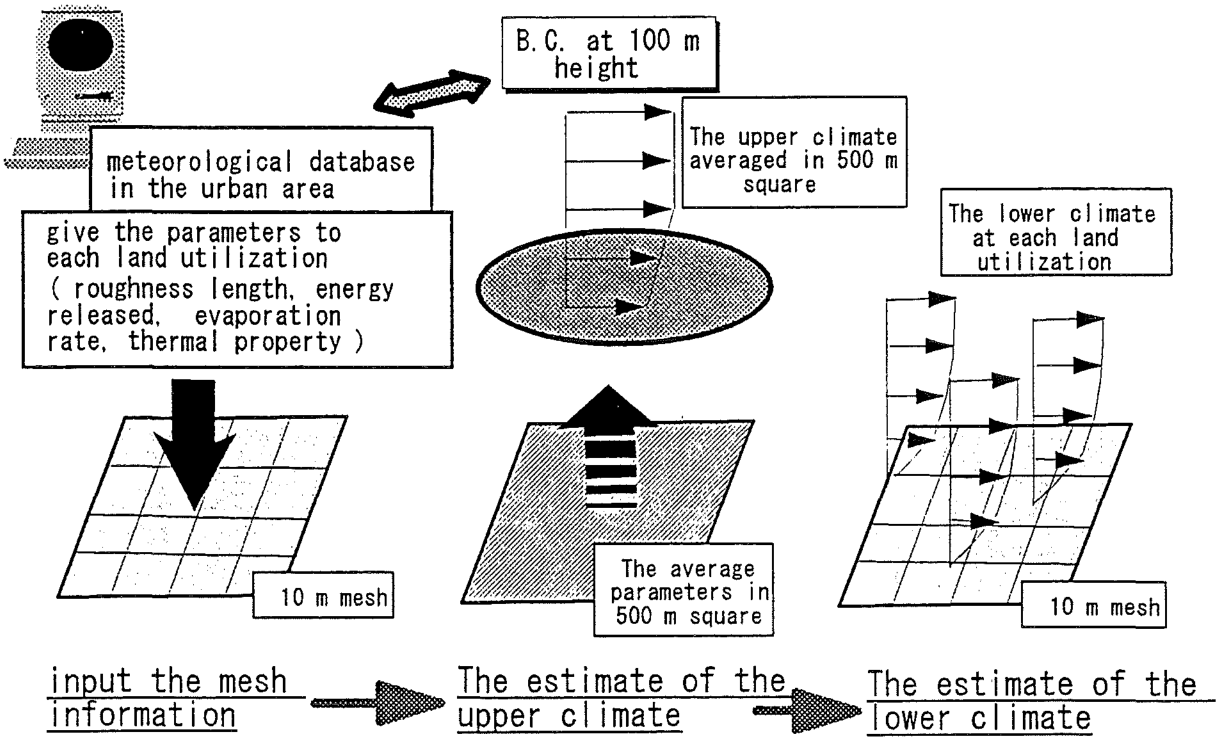

Figure 2 The predictive model

CASE STUDY

Outline

Here, we select residence, park and road as most fundamental land use categories and set up the area ratios and the parameters. A series of case studies, plan (A), plan (B), plan (C), plan (D), is executed. The categories, ratios and parameters are shown in Table 1. The analyzed area is 25 ha. Plan (A) means a lower residential district with bulk ratio 100%. The total floor area is 18.75 ha. In plan (B), middle higher building with bulk ratio 240 % is used and the ratio of the park area increases from 5 % to 49 %. The total floor area is same as plan (A). Plan (C) is a case in which energy used in the residence and the road reduce half. Plan (D) examines the effect of the introduce of the small sized green. The area of 45 % is planted in the residence and 50 % of the road is planted in the road. The total green area of this plan is same as Plan (B).

table 1 The categories and the parameters for the case studies

PLAN	category	area (m^2)	Z0 (m)	f	HEAT (kcal/ m^2/DAY)	a	ε	λ (kcal/m /h/℃)	CR (kcal/ m^3/°C)
(A)	residence	187500(75%)	1.27	0.0	238.2	0.8	1.0	1h=.0	500
	park	12500(5%)	0.5	0.5	0.0	0.8	1.0	1.0	500
	road	50000(20%)	0.5	0.0	600.0	0.8	1.0	1.0	500
(B)	residence	78125(31%)	1.85	0.0	571.7	0.8	1.0	1.0	500
	park	121875(49%)	0.5	0.5	0.0	0.8	1.0	1.0	500
	road	50000(20%)	0.5	0.0	600.0	0.8	1.0	1.0	500
(C)	residence	187500(75%)	1.27	0.0	119.1	0.8	1.0	1.0	500
	park	12500(5%)	0.5	0.5	0.0	0.8	1.0	1.0	500
	road	50000(20%)	0.5	0.0	300.0	0.8	1.0	1.0	500
(D)	residence	187500(75%)	1.27	0.23	238.2	0.8	1.0	1.0	500
	park	12500(5%)	0.5	0.5	0.0	0.8	1.0	1.0	500
	road	50000(20%)	0.5	0.25	600.0	0.8	1.0	1.0	500

Meteorological data

The typical data in August in Tokyo, Japan is used for the calculation. The change of solar radiation is shown Figure 3. We fixed the variables, i.e. absolute humidity 0.0154 g/kg, atmospheric radiation 370 kcal/m² h, wind velocity at 100 m height 3 m/s, air temperature at 100 m height 24.7 °C.

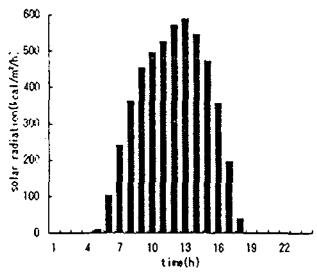

Figure 3 Solar radiation in August, TOKYO, JAPAN

Table 2 Results

PLAN	the upper (h=10m)	residence (h=2m)	park (h=2m)	road (h=2m)
(A)	27.13	27.81	26.40	27.87
(B)	26.69	27.47	26.18	27.43
(C)	27.02	27.67	26.38	27.71
(D)	26.67	26.57	26.19	26.81

RESULTS

The daily mean temperatures are shown in Table 2. The temperatures at 2 m height vary from the land utilization. The values are 26.2 °C ... 27.9 °C. The temperature at the residence or the road in which no evaporation occurs and artificial heat released are higher than the park's one. The upper zone's temperature are formed by the ratios of such lands. The values are 26.7 °C ... 27.1 °C.

The fluctuations of atmospheric temperatures at 2 m height are as follows. Figure 4 displays the result of Plan (A) as the standard. The temperature of the residence is higher than the park's one all day long and is similar to the road's one. The difference of temperatures between residence and park is 1.8 °C in day time and is 1.0 °C at night. The temperatures of plan (B) is shown in Figure 5. The residence's temperature go down in comparison with plan (A) and the degree is 0.5 °C in day time, 0.3 °C at night. The result of plan (C) is shown in Figure 6. The temperature in the residence isn't different from the plan (A)'s one. We can see the difference between plan (A) and plan (C) at night. The degree is about 0.2 °C. Figure 7 displays the plan (D)'s result. The temperature of residence go down to the park's level. The degree of cooling is 2.1 °C in day time and is 0.6 °C at night.

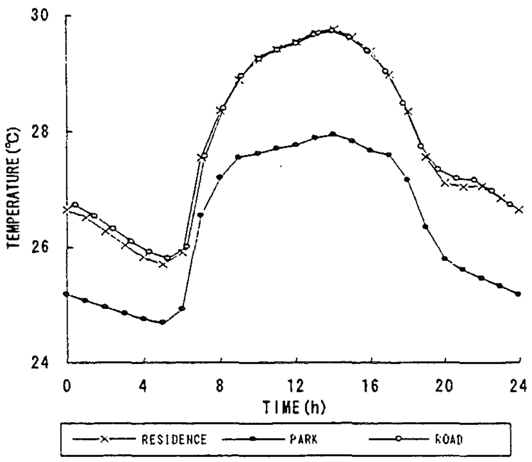

Figure 4 Air temperature at 2 m height
【 Plan (A) : standard 】

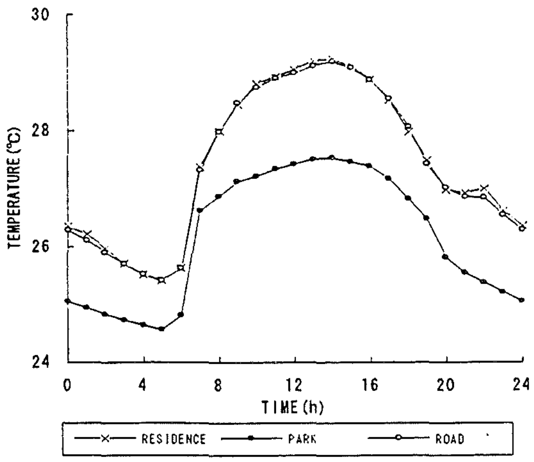

Figure 5 Air temperature at 2 m height
【 Plan(B) : expansion of park area 】

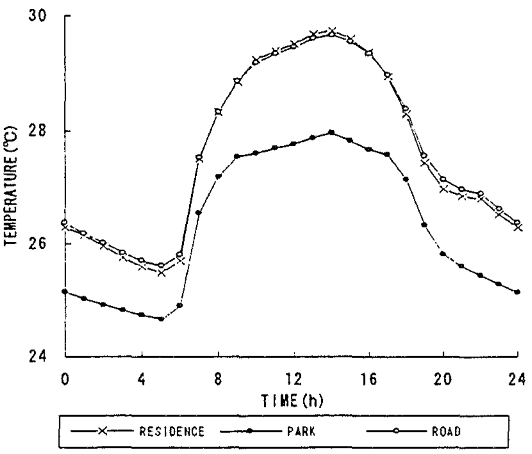

Figure 6 Air temperature at 2 m height
【 plan(C) : energy conservation】

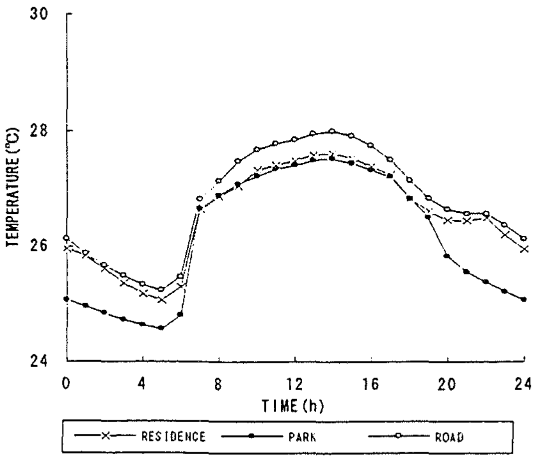

Figure 7 Air temperature at 2 m height
【 plan(D) : small sized planting 】

CONCLUSION

A parametric study is carried out to find the effect on the air temperature. The numerical results shows small planting in the residence is so effective way to decrease air temperature.

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ONE- AND TWO-DIMENSIONAL NUMERICAL SIMULATION OF ATMOSPHERE IN AN URBAN AREA

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ABSTRACT

The various factors which influence the thermal and atmospheric condition in an urban area should be predicted and considered in the city planning for the comfortable and healthy city. One- and two-dimensional numerical simulation of the atmosphere in an urban area are described in this paper. The artificial factors of urban thermal condition are the configurations and materials of the ground and buildings and artificial heat exhaust, while the natural factors are the solar radiation and the wind. These factors are reflected in the simulation models as the initial and the boundary conditions and the parameters of the simulation. One-dimensional simulation, which means the vertical model of the atmospheric layer, reveals the difference of air temperature by the level of urbanization. Two-dimensional models, which means the model of turbulent air flow, presents the distributions of the wind and air temperature in a certain area.

1. INTRODUCTION

Thermal conditon in a built-up area is one of the most important elements in city planning. The thermal environment is formed by various factors, for example buildings, ground covering materials and artificial heat exhaust as artificial factors, wind, solar radiation and evaporation as natural factors. They influence ont only the thermal environment in an urban area but also themselves one another. Therefore, it is not easy to consider these factors in city planning. It is necessary to simulate the thermal preformance in an urban area including thses factors to plan a comfortable and healthy city, since it is almost impossible to do full scale experiments.

If the ground and atmosphere of an urban area are regarded as uniform, which is a rough but necessary supposition for the simulation of rather large scale area, only the vertical distribution of thermal factors have to be simulated. That is the one-dimensional (1-D) model for the numerical simulation of atmospheric environment in an urban area.

If the land-use of a certain urban area have to be planned appropriately, the effects of the change of the ground surface on the thermal condition in the area should be considered. However, a 1-D model can not express the horizontal changes of the surface. Actual phenomena have to be simulated by a three-dimensional model; however a two-dimensional model with the axes of streamwise direction and vertical direction can present the changes of the surface. That is the two-dimensional (2-D) model for the numerical simulation of air distribution in an urban area.

2. ONE-DIMENSIONAL MODEL

2.1 Atmospheric layers

The 1-D model used here is the model of the planetary boundary layer of which the area is from the ground surface to a height of 1000 m. Almost all the weather phenomena take place in this layer. The area is separated into two layers; one is the surface boundary layer up to about 100 m, and the other is the Ekman boundary layer over the former. Then, the lower part of the former is thought to be a special layer which is the space between buildings. It is called the canopy layer which is as high as the average height of the buildings. The solid layer under the surface of the mixture of ground and buildings up to a depth of 50 cm is also considered in the model. The whole area of this 1-D model described above is shown in Figure 1.

2.2 Ekman boundary layer

The turbulent diffusion equations of potential temperature and specific humidity are solved in the Ekman layer. The terms of the differentials by horizontal direction in the transport equations of the variables are ignored in this model. These equations are shown in Table 1. The eddy diffusion coefficients of potential temperature and specific humidity are thought to be the same values in the Ekman layer which are given by O'brien's equation [1]. They are 0 at the upper boundary and continuous to the surface boundary layer at the lower boundary. The wind speed in the Ekman layer is thought to be uniform and equal to that at upper boundary of surface layer.

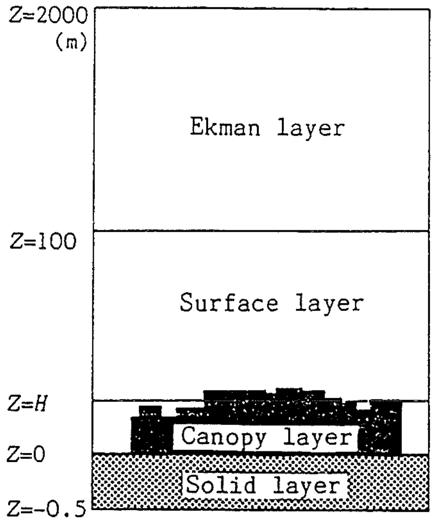


Fig. 1 Outline of the one-dimensional model.

2.3 Surface boundary layer

Another name of the surface boundary layer is the constant flux layer which means that the flux of momentum, heat and vapor are uniform in this layer. Since Monin-Obukhov's similarity law [2] can be applied in this layer, the vertical distributions of the variables, for example potential temperature and specific humidity, are given by the universal functions. The universal functions used here are given by J. Kondo et al [3]. The equations used in this layer are shown in Table 2.

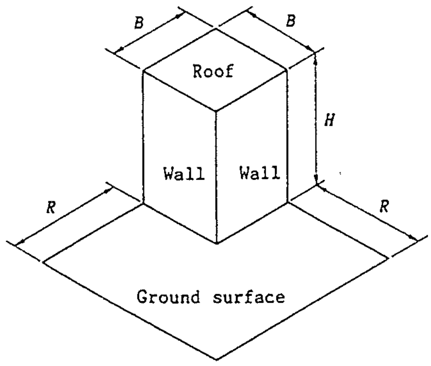


Fig. 2 Layout of buildings.

Table 1 Equations of Ekman boundary layer.

$\frac{\partial T}{\partial t}=\frac{\partial}{\partial z}(K_h\frac{\partial T}{\partial z})$ $\frac{\partial q}{\partial t}=\frac{\partial}{\partial z}(K_e\frac{\partial q}{\partial z})$	t = time Z = vertical coordinate T = potential temperature q = specific humidity K_h = eddy diffusion coefficients of potential temperature K_e = eddy diffusion coefficients of specific humidity

2.4 Canopy layer and solid layer

The wind speed, air temperature and other variables are thought to be uniform in the canopy layer. The configurations of buildings are considered as the increase in the surface area in the model. The shape of buildings are supposed to be simple cubes as shown in Fig. 2. The solar radiation and the nocturnal radiation are calculated on the upper boundary of the canopy layer of which the solar absorptance and the infra-red radiation emissivity are supposed. The radiation on the actual surface is considered as a parameter. The heat flux in the solid layer is calculated as the heat conduction through a mixture of the ground and buildings.

Table 2 Equations of surface boundary layer.

$$\frac{\partial U}{\partial z} = \frac{U_*}{\kappa z}\phi_m(\zeta)$$

$$\frac{\partial T}{\partial z} = \frac{T_*}{\kappa z}\phi_h(\zeta)$$

$$\frac{\partial q}{\partial z} = \frac{q_*}{\kappa z}\phi_e(\zeta)$$

$$T_* = \frac{Q_H}{\rho C_p U_*}$$

$$q_* = \frac{Q_E}{l C_p U_*}$$

$$\zeta = \frac{z}{L}$$

$$L = \frac{-U_*^2 T_0}{\kappa g T_*}$$

U = wind speed	ρ = specific gravity of air
U_* = friction speed	C_p = specific heat of air
T_* = friction temperature	l = latent heat of evaporation
q_* = friction humidity	Q_E = latent heat flux in surface layer
κ = Karman constant	Q_H = sensible heat flux in surface layer

Universal functions

$-2 \le \zeta \le 0$:	$\phi_m = 0.98(1\text{-}16.4\zeta)^{-1/4}$
	$\phi_h = \phi_e = 0.98(1\text{-}16.4\zeta)^{-1/2}$
$0 \le \zeta \le 0.3$:	$\phi_m = \phi_h = \phi_e = 1+6\zeta$
$0.3 \le \zeta$:	$\phi_m = \phi_h = \phi_e = (1+22.8\zeta)^{1/2}$

2.5 Examination of accuracy

The results by the 1-D model is compared with the field observation data [4] to examine its accuracy. The field observation is described in the following section, two-dimensional model. The 1-D model is reformed and its height is limited to 80 m that is the same height as the field observation. The air temperature of the field data at a height of 80 m is given to the 1-D model as the upper boundary condition.

The air temperature at a height of 5 m by the 1-D model is compared with that of the field data in Fig. 3. The calculated values correspond to the field data without the data at 24:00. The vertical distributons of the air temperature are shown in Fig. 4. The measured air temperature at 24:00 is detached from the profile of air temperature calculated by the 1-D model in the lower part. The reason is the wind direction. The observation point is located at the changing point between a built-up area and a park with a water pond. The wind is blowing from the built-up area in the daytime, that is the sea breeze, and it changes to the land breeze in the nighttime that is blowing from the park. However, the land breeze was very weak and its effect appeared only at the midnight. The change of the wind can not be considered in the 1-D model.

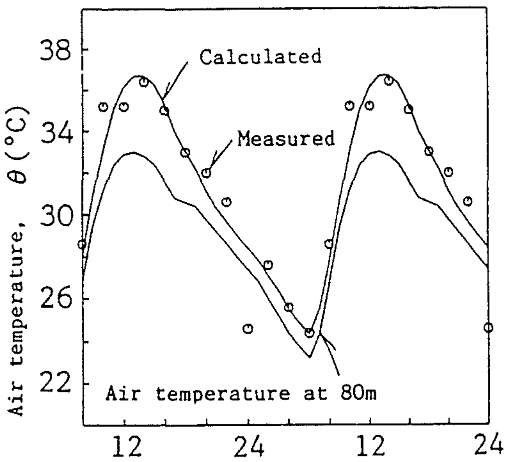


Fig. 3 Comparison between maesured and calculated air temperature at a height of 5m.

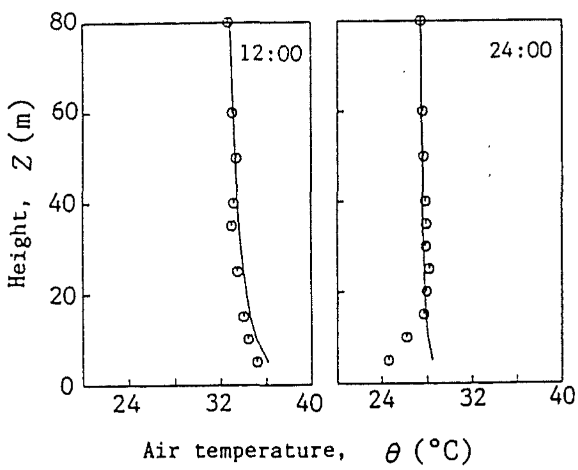


Fig. 4 Comparison between maesured and calculated air temperature profiles.

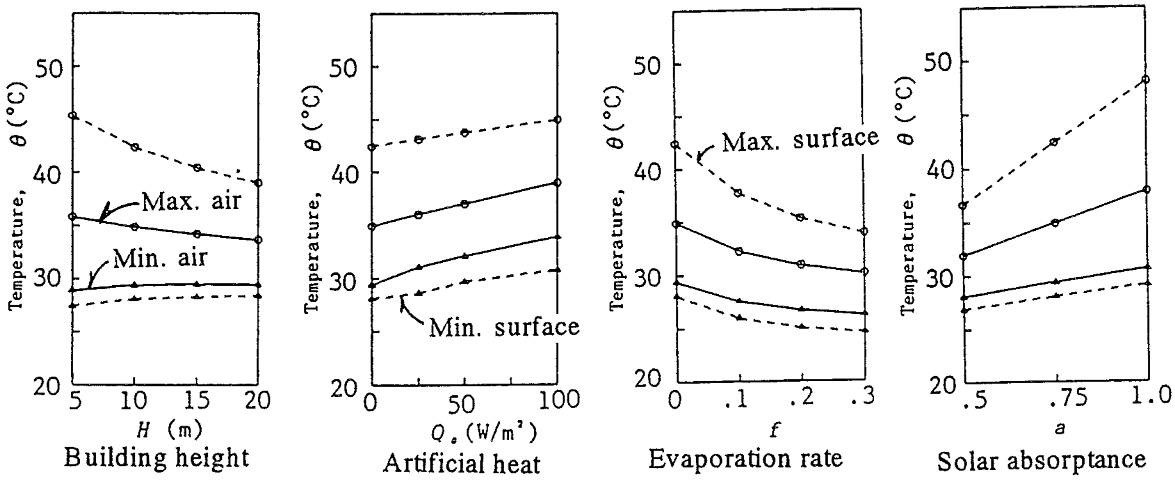


Fig. 5 Changes of temperature by several factors in the one-dimensional model.

2.6 Parameter analysis

Several factors which influence the thermal environment in an urban area are selected as the parameters of the 1-D model. They are building height, artificial heat exhaust, evaporation ratio and solar absorptance on the surface. The surface means the mixture of the ground and buildings. The changes of four kinds of temperature, maximum and minimum air temperature, maximum and minimum surface temperature, by these parameters are shown in Fig. 5. These data are the values of the second day in the simulation.

If the artificial heat and solar absorptance increase, all the temperature rises simply, and this tendency reverses when the evaporation ratio increases. However, the higher buildings, the lower the maximum temperature and the higher the minimum temperature.

3. TWO-DIMENSIONAL MODEL

3.1 Simulation area

A 2-D model needs a limited area in the streamwise and the vertical directions. The simulation area is modelled after the field observation [4]. The field observation was carried out in the downtown of Fukuoka, Japan. The measurement items in the field observation are the profiles of air temperature and the wind at three points. They were measured by three tether sondes. The height is limited to 80 m because of air traffic control. One observation point was set on the coastline, which is called point A, and another was set at 2000 m from the coastline along the main wind direction, which is point C. The main wind in this area is the sea-land breeze. The third point is set at 1200 m from the coastline, which is called point B. The region between point A and point B is a built-up area, and that between point B and point C is a park with a large water pond

This observation area is simplified for numerical simulation model as shown in Fig. 6. The objective wind simulated by a 2-D model is the sea breeze. Therefore, point A is the inflow boundary. The profiles of the mean wind speed and turbulence intensity of the sea breeze of the field observation are shown in Fig. 7.

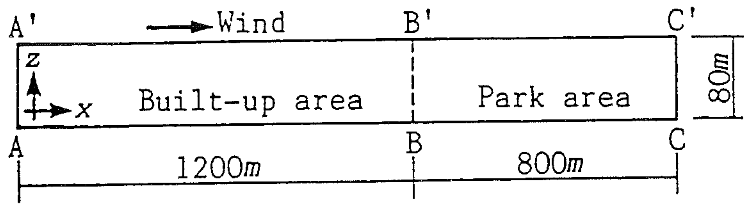


Fig. 6 Simulation area of the two-dimensional model.

The mean wind speed is dotted in log-log scale to adapt the power law. The exponents at point B and point C are 1/4 and 1/8, respectively. These power law is used as the ground boundary conditions. The profile of turbulence intensity at point A can be approimated to two straight lines.

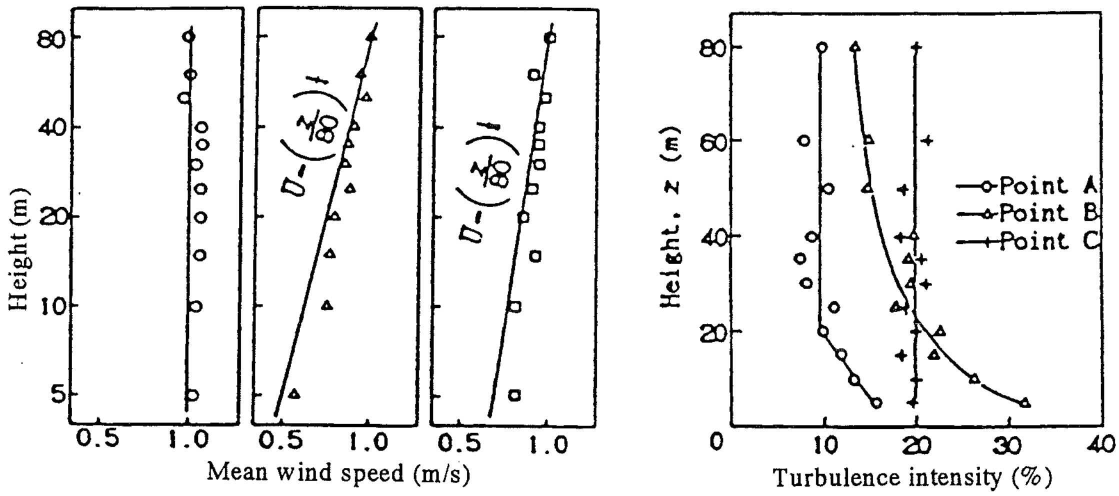


Fig. 7 Profiles of wind speed and turbulence intensity measured by tether sondes.

The profile of air temperature at point A is also almost uniform, though it is not shown here. They are used as the inflow boundary conditions of a 2-D model. The buildings in the simulation area are not modelled exactly. They are treated as a roughness parameter on the ground surface. The boundary condition on the ground is shown in Fig. 8

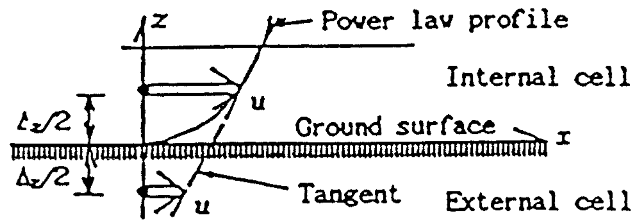
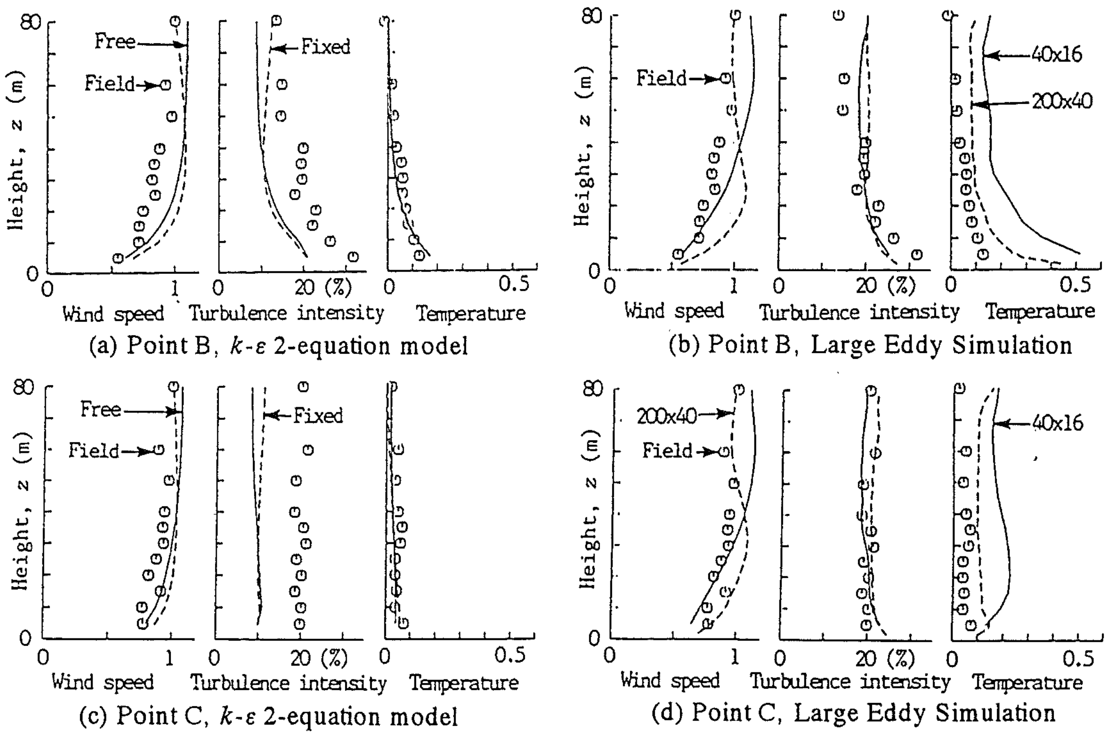


Fig. 8 Boundary condition on the ground surface.



(a) Point B, k-ε 2-equation model

(b) Point B, Large Eddy Simulation

(c) Point C, k-ε 2-equation model

(d) Point C, Large Eddy Simulation

Fig. 9 Comparisons between the field data and the numerical calculation results.

3.2 Numerical simulation of turbulent air flow

The wind which is regarded as turbulent air flow and air temperature distributions in the area have to be simulated. Therefore, the 2-D model described here is the numerical simulation of non-isothermal turbulent air flow, which means one of the application of Computational Fluid Dynamics (CFD). The basic equations of fluid dynamics are used for the simulation.

Two types of mathematical models of turbulence are tested here; one is Large Eddy Simulation (LES) [5] and the other is 2-equation model [6].

3.3 Large Eddy Simulation

The equations for LES used here are Deardorf-Smagorinsky model. The Smagorinsky constant is 0.12. The grid where the calculation points are set is a very important element in the LES, since the filter length is calculated from the grid scale directly. Therefore, two types of calculation grid are tested; one is 40 • 16 that means x- and z-direction lengths are divided into 40 and 16 and the other is 200 • 40.

3.4 k-ε 2-equation model

The equations of k-ε 2-equation model used here are normal k-ε 2-equation model on the basis of isotropic turbulence. The calculation grid for 2-equation model is 40 •16. Two types of boundary condition for temperature at upper boundary is examined; one is the free slip condition which means adiabatic condition and the other is the constant temperature.

3.5 Results of numerical simulation

The calculation results are expressed as the profiles of mean wind speed, turbulence intensity and air temperature. They are compared with the field data at two observation points, point B and Point C in Fig. 9. The profiles of mean wind speed and air temperature by the 2-equation model at both the points agree well with the field data. However, the turbulence intensity by the 2-equation model is smaller than of the field data. The results of the LES on the grid of 40 • 16 differ from the field data, while those of 200 • 40 agree well.

4. CONCLUSIONS

Though the 1-D model can not express the changes of the ground surface, it can be applied to predict the fluctuations of air and surface temperature and the wind. It is also useful for the parameter analysis to estimate the influence of urbanization on the thermal environment. On the other hand, the 2-D model can solve the detailed distributions of the air flow and air temperature, although they are steady conditions. If the 2-D model is adapted to time-dependent air flow, it needs enormous calculation time. The combination of the 1-D and the 2-D models is very important, since both the fluctuation and the detailed distribution of urban thermal environment are needed for the better plan of comfortable and healthy city.

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URBAN BOUNDARY LAYER
- A CASE STUDY -

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ABSTRACT

In this paper the evolution of potential temperature profiles is compared at two stations, located in and outside Karlsruhe on a fair weather late summer day. Most important differences are shown to exist between the atmospheric boundary layer in and outside the city of Karlsruhe. In addition, a cross-over effect is investigated. It is shown that a cross-over effect can only be postulated if the two stations intercompared are situated on a line parallel to the wind direction.

1. INTRODUCTION

During several days in September 1986 measurements have been accomplished in and around Karlsruhe. Besides other systems, two tethered balloons and two radiosonde systems were used. With these systems the parameters temperature, humidity, wind velocity, and wind direction were monitored.

The aim of the measurements was to investigate the most striking differences between an urban boundary layer and a rural boundary layer during a typical fair weather late summer period. Two kinds of considerations were of interest: the comparison of the urban boundary layer with (1) the upstream and (2) the downstream rural boundary layer. In this paper only subjects related to case no. (1) are presented.

2. AREA OF INVESTIGATION AND MEASUREMENT SITES

Figure 1 shows the area of Karlsruhe. The map gives an overall view of the most densely populated parts of the town, the industrial zones as well as the surrounding areas.

In the densely populated parts most of the houses are 4 to 5 storeyed and their heights range from about 20 m to 25 m. There are also some higher buildings such as steeples and high buildings of insurance and utility companies. However, they do not form clusters and are not numerous. The typical distances between the towered buildings are some hundreds of meters.

North of the "Innenstadt" the outskirts of Karlsruhe are wooded areas. Also outside Karlsruhe, in north-west and north-east directions small suburbs and arable land are dominating.

The radiosondes and the tethered balloons were sited at the locations marked in Figure 1:

- radiosonde Neureut: north of Karlsruhe and north of the small Heide residential area (rs1),
- radiosonde Forchheim: south-west of Karlsruhe at the Karlsruhe airfield (rs2),
- tethered balloon Castle: in front of the Karlsruhe Castle in the center of a free space between the Castle and the first houses of the city (tb1),

- tethered balloon IWKA: in a former industrial zone near the south-western city border (tb2).

When the sites were selected the idea was to provide the sites along a line running from north-east to south-west. Especially the locations of the two tethered balloons and the locations of the radiosonde at Forchheim fulfil this requirement. When the campaign was planned an anticyclonic weather situation with prevailing winds from north-east was awaited. Therefore, the stations mentioned are located along a line parallel to the expected wind direction. The distance between the tethered balloon at the Castle and the tethered balloon at IWKA was about 1.3 km.

3. WEATHER CONDITIONS

One special period of observation lasted from 6 a.m. Central European Summer Time (CEST) on September 10 to 5 a.m. on September 11, 1986. The synoptic situation was dominated by a high pressure system, which was centered above France and which totally covered the west of Europe. Karlsruhe was located in the peripheral zone of that system. The day of September 10 and also the night to September 11 were cloudfree. The incoming short-wave radiation was not disturbed during the first day of the special observation period. Also the incoming atmospheric long-wave radiation exhibited only little variations during the night.

In Figure 2 the wind directions monitored at the tethered balloon stations at altitudes of around 300 m are shown for the special days of investigation. The wind direction varied between about 0 and 75 degrees; during most of the time the wind came from directions of 45 to 65 degrees. The wind velocity was mostly very high. In Figure 3 the velocity is shown for different heights at the IWKA station in the course of the day. At 300 m height the maximum value was 8.5 m/s; the minimum value was 0.5 m/s at 25 m height. Whereas the wind velocities decreased at greater heights during daytime and increased during nighttime, the velocities were reversed at lower heights. At the lower altitudes, the maximum values were measured during daytime, the minimum values during nighttime. The curves plotted for different heights show some crossings which are due to non-simultaneous monitoring of the wind velocities. The data points have been taken one after the other. Each data point represents a one minute average. The sampling frequency was 0.1 Hz.

At 4.30 p.m. the well mixed boundary layer attained its largest extension of about 1500 m.

4. PROFILES OF POTENTIAL TEMPERATURE IN AND OUTSIDE THE CITY OF KARLSRUHE

In Figure 4 profiles of potential temperature (Tpot), monitored by the tethered balloons, are shown for different times of the day. From these and other profiles the following conclusions can be drawn:

(1) At night and in the early morning the inversion layer was always surface based at the Castle. At the IWKA site this was the case only during four hours for the period from 9 p.m. to 1 a.m. During all other periods at night the inversion was elevated at the IWKA site.

(2) When the inversion was elevated, the atmosphere below the inversion was always neutral or characterized by slightly unstable or slightly stable stratification at the IWKA site.

(3) Both inversion layers were generated in the evening hours at similar times: the surface based inversion at the Castle at about 7 p.m., the elevated inversion at IWKA at about 8 p.m. Sunset was at about 7 p.m.

(4) At IWKA the base of the elevated inversion was always found at about 50 m height.

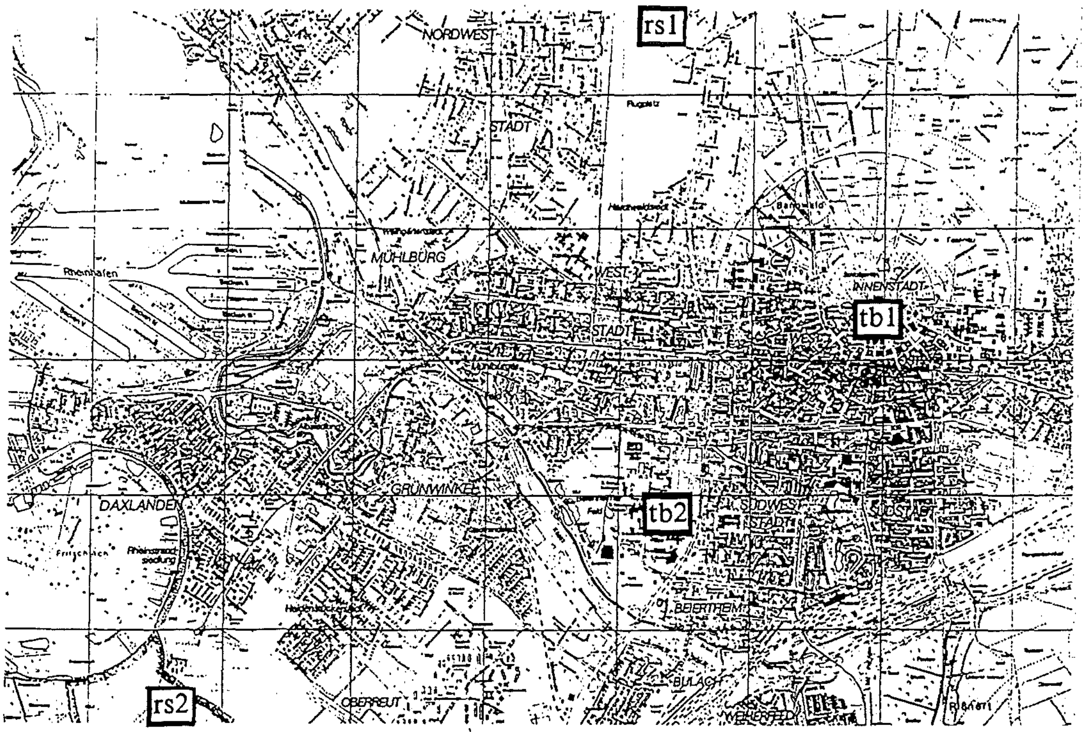

Fig. 1: Map of the city of Karlsruhe. The locations of the tethered balloon stations are marked by tb1 (Castle) and tb2 (IWKA), the radiosonde stations by rs1 (Neureut) and rs2 (Forchheim).

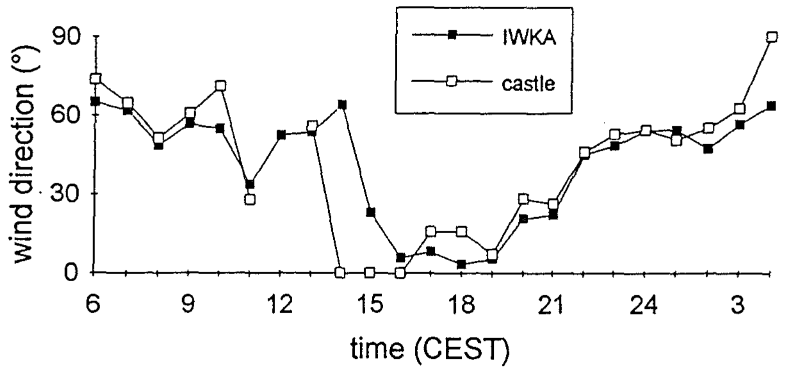

Fig. 2: Wind direction at castle and IWKA-station in the course of Sept., 10th, 1986.

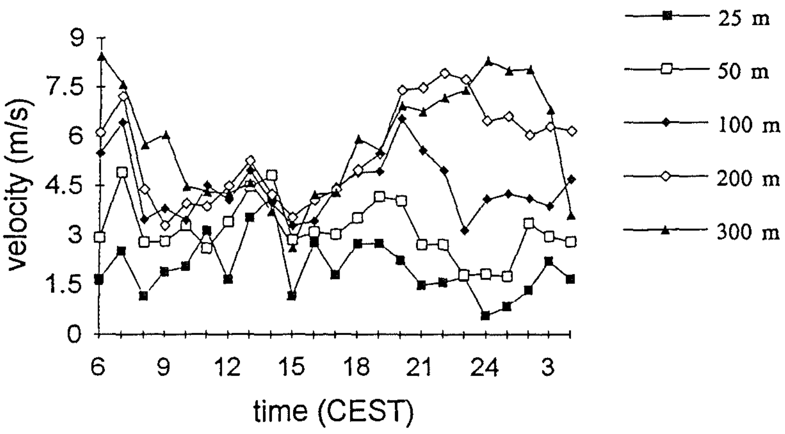

Fig. 3: Wind velocity at IWKA-station in different heights in the course of Sept. 10th, 1986.

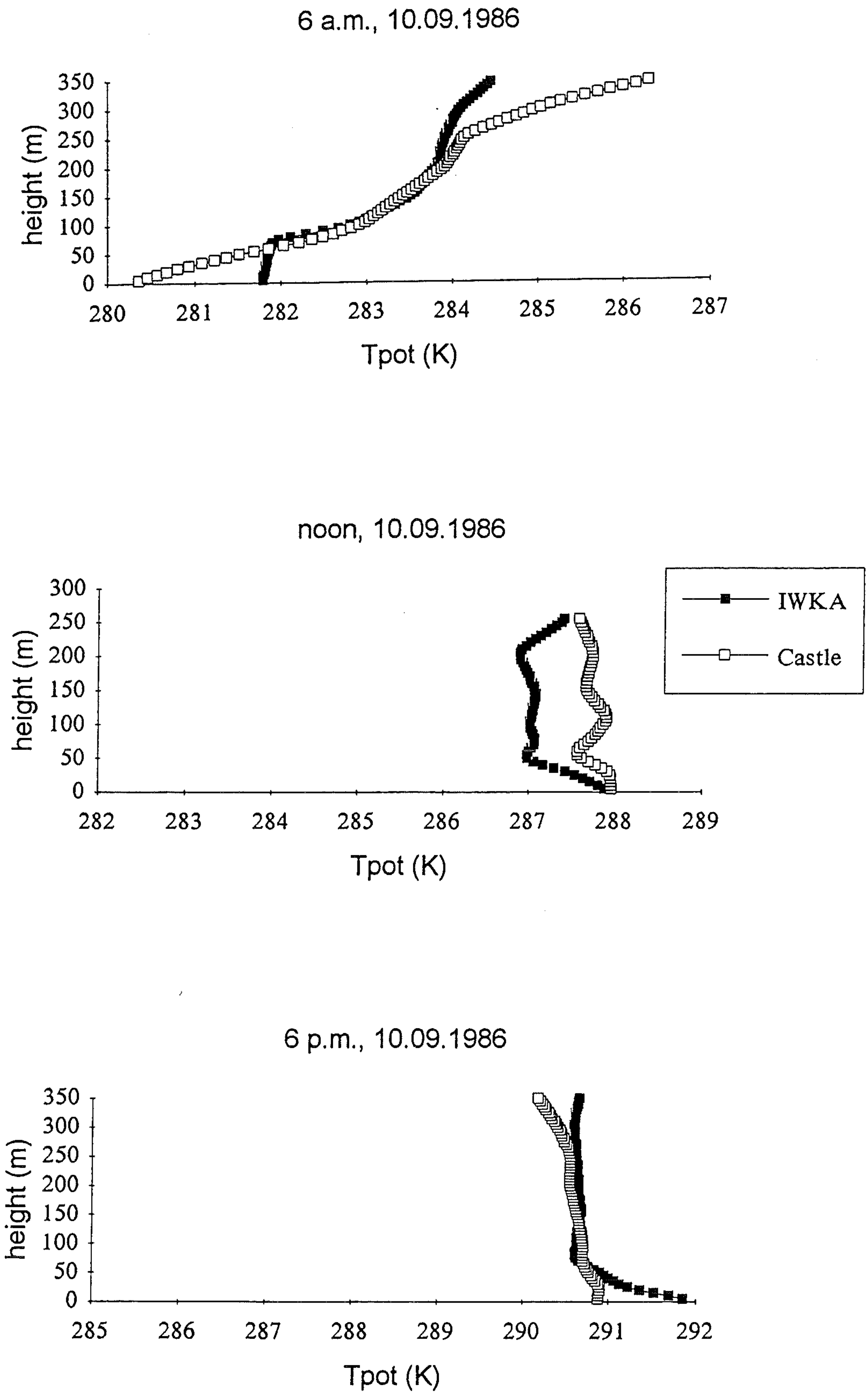

Fig. 4: Profiles of potential temperature at Castle and IWKA site at different times of the day.

(5) In the morning at sunrise (about 6 a.m.), an elevated inversion layer could still be observed at the IWKA; at the Castle the inversion was still surface based at the same time (see Figure 4).

(6) At 8 a.m. (2 hours after sunrise) the lower layers of the atmosphere became already warmer. On account of warming up, the profile became neutral in these layers at the Castle and already unstable at IWKA. As a result of the onset of mixing, a temperature reduction was measured compared to the profiles taken one hour earlier: at the Castle in a range of 50 m to 120 m height (max. reduction: about 1 K), at IWKA in a range of 80 m to 350 m height (max. reduction also about 1 K).

(7) At 9 a.m., both profiles are unstably stratified in the surface layer. At the IWKA site the unstable layer extended up to about 75 m height, the well mixed layer up to more than 200 m. At the Castle the unstable layer was detected up to 50 m height, the well mixed layer up to 150 m. At that time the temperature was lower above the Castle than above IWKA at all altitudes.

(8) After 11 a.m. to 1 p.m. a change was observed. At all heights at IWKA, the boundary layer became cooler than the boundary layer above the Castle site starting at 11 a.m. (Figure 4). At 1 p.m. this effect was still be observed, but was already weaker.

(9) At IWKA daytime warming in the complete mixing layer took place until at least 5 p.m. The same applies for the Castle site.

(10) After 5 p.m. cooling of the boundary layer started at both stations. Although in the surface layer the temperature structures were still unstable, cooling was observed in the whole mixed layer. Cooling was such that in a first approximation the profile taken at 6 p.m. was identical to the 5 p.m. profile (Figure 4), but shifted to lower temperatures. This holds for both stations.

(11) At the Castle the temperature structure in the surface layer started to become stable after 7 p.m.; at IWKA this process began between 8 and 9 p.m.

(12) At midnight, the stratification was much more stable at the Castle (0.07 K/m) than at IWKA (0.02 K/m). Whereas the profiles were stably stratified at the Castle site during the whole night, at IWKA growing instability was observed, starting shortly after 1 a.m.

5. CROSS-OVER EFFECT AT NIGHT

The profiles for 9 p.m. are not shown in Figure 4, but in Figure 5. From 8 to 9 p.m. both profiles, the Castle profile and the IWKA profile, changed in such a way that a so called cross-over effect developed. Cross-over means that above the city in a certain range of heights the atmosphere is cooler than the atmosphere outside the town. The cross-over effect developed in the height interval between 50 m and 220 m. The maximum difference was near 1 K at about 80 m height. The question is: Where does this effect come from? In the literature (e. g. Kraus, 1979) the explanation is that the atmosphere above the city is well mixed from bottom up to a certain height and, therefore, it is cooler than outside the city where the conditions are very stable, and at heights above, for example, 50 m the relatively warm air is not cooled by mixing processes. This explanation does not hold in the present case. The atmosphere above the city was stably stratified (Figure 5).

Looking at the cooling rates (temperature change per hour) of the different profiles from 8 to 9 p.m., the following charcteristics can be found: In the given height interval from the surface up to 220 m the cooling rate decreases with increasing height at both stations:

cooling rate at the IWKA site: -1.2 K/h (50 m), -1.1 K/h (80 m), -0.4 K/h (150 m)
cooling rate at the Castle site: -1.0 K/h (50 m), -0.3 K/h (80 m), -0.2 K/h (150 m)

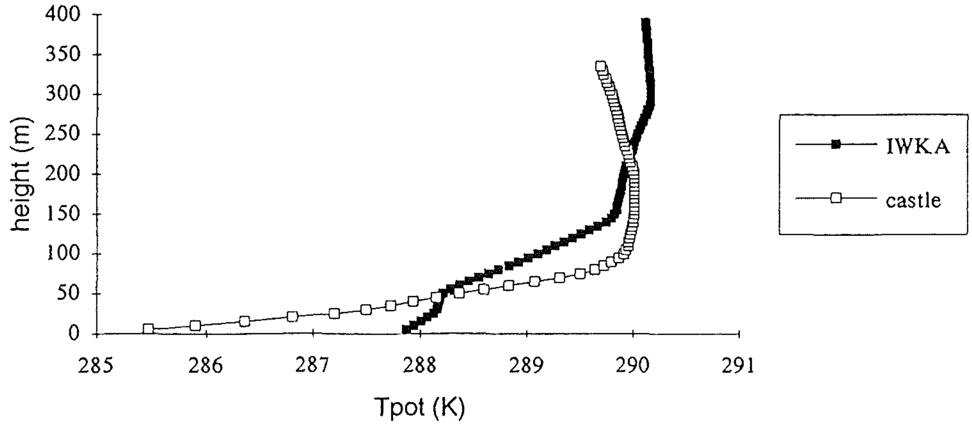

Fig. 5: Profiles of potential temperature at castle and IWKA site at 9 p.m., September 10, 1986. A cross over effect can clearly be seen.

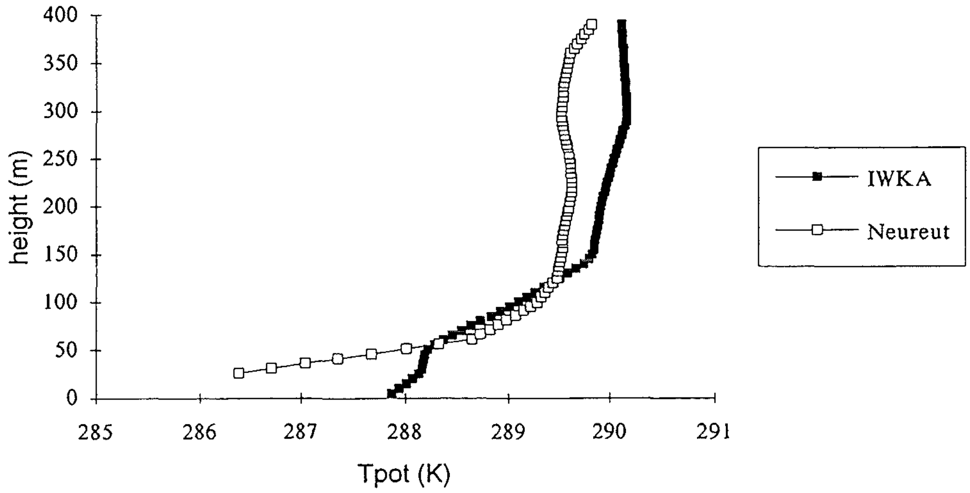

Fig. 6: Profiles of potential temperature at Neureut and IWKA site at 9 p.m., September 10, 1986. In comparison to Fig. 5 the cross over effect is here very much smaller.

It can be seen that the cooling rate was larger at the IWKA site than at the Castle site in the height range from the surface up to 220 m. Above 220 m the cooling rate is reversed.

It is assumed that an advective process is responsible for cross-over. Reasons for this assumption are the stable stratification of the IWKA profile and the height range where the maximum cooling rate can be measured (80 m). Looking at the wind direction, the following scenario appears:

Castle (8 p.m.):	50 m: 15°	80 m: 14°	220 m: 22°
Castle (9 p. m.)	50 m: 23°	80 m: 12°	220 m: 18°
IWKA (8 p. m.)	50 m: 15°	80 m: 10°	220 m: 16°
IWKA (9 p. m.)	50 m: 35°	80 m: 23°	220 m: 16°.

This means that the air parcels whose status was monitored by the tethered balloon at the Castle did not pass the IWKA sonde. Therefore, in Figure 6 the profiles taken at 9 p.m. are shown which were monitored at the IWKA and at the Neureut radiosonde stations. The direction of the line running from the Neureut radiosonde station to the IWKA tethered balloon station was exactly from north to south. The comparison of the profiles of these two stations shows that there was also a cross-over effect but much smaller in size. The maximum difference was in the size of 0.25 K. The result shows that one has to be careful in postulating cross-over effects if the stations intercompared are not located along a line parallel to the wind direction. On account of the inhomogeneity of land use outside the city, the air parcels which arrive at different upwind city border locations can show considerable differences in their conditions.

6. CONCLUSIONS

The potential temperature profiles indicated give an impression of the differences appearing between the conditions of the atmospheric boundary layer outside (upwind) and in the city of Karlsruhe in the course of a day. Most striking differences and effects have been shown. Nevertheless, the analytical results given in sections 4 and 5 are qualitative results. To gain deeper insight into the topics of the investigation, also the other monitored parameters, results of analytical process studies as well as simulation results of numerical models have to be taken into account.

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THE ECOLOGICAL CITY SUBCOMMITTEE UNDER THE ARCHITECTURAL INSTITUTE OF JAPAN AND ITS STUDY

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ABSTRACT

The Architecture and Earth Environment Special Committee was established under the Architectural Institute of Japan in 1990. The Ecological City Subcommittee is one of subcommittee under this special committee.

This paper describes that a concept of "the Ecological City" in Japan, this subcommittee's policy, and studied contents.

1. INTRODUCTION

The earth environment is a worldwide matter of concern. In Japan, committee or laboratories are established under the Environment Agency, the National Land Agency, the Ministry of Construction and the Ministry of International Trade and Industry.

The Architecture and Earth Environment Special Committee was established under the Architectural Institute of Japan (AIJ) in 1990.

The chairmen are Prof. Yoh Matsuo (1990-1992) and Prof. Masahito Yasuoka (1992-1994).

The purpose of its study are to clear how the AIJ should grapple with the earth environmental problems, to show concrete data which explain the influences of the architecture on the earth environment and to make the basic plan for our future activities.

This committee consists of 9 subcommittee; (1) life style: (2) use of resources: (3) life cycle CO_2: (4) passive and low energy architecture: (5) regional planning (rural planning): (6) regional planning (urban planning): (7) ecological city: (8) modeling of urban climate: (9) environmental changes.

2. MEMBERS OF THE ECOLOGICAL CITY SUBCOMMITTEE

A total of 17 members take part in the Ecological City Subcommittee. The Members are as follows.

Chairman;

Toshio Ojima (Prof., Waseda Univ.)

Secretaries;

Hironori Watanabe (Waseda Univ.)
Hirotoshi Yoda (Univ. of Kinki)

Members; (1990-1994)

Akira Hoyano (Prof., Tokyo Institute of Technology)
Fujio Kimura (Tohoku Univ.)
Masakazu Moriyama (Kobe Univ.)

Ken-ichi Narita (Hiroshima Univ.)
Tateo Oka (Prof., Utsunomiya Univ.)
Nobuyuki Takahashi (Waseda Univ.)

(1990-1992)

Shunji Suzuki (Japan Environmental Systems Corp.)
Yutaka Tonooka (Institute of Behavioral Sciences)

(1992-1994)

Weijun Gao (Waseda Univ.)
Nobuhiko Hamada (Shimizu Corp.)
Tadahisa Katayama (Prof., Kyusyu Univ.)
Hitoshi Kouno (Osaka Municipal Government)
Hiroshi Miyazaki (Himeji Institute of Technology)
Atsumasa Yoshida (Okayama Univ.)

3. A CONCEPT OF THE ECOLOGICAL CITY IN JAPAN

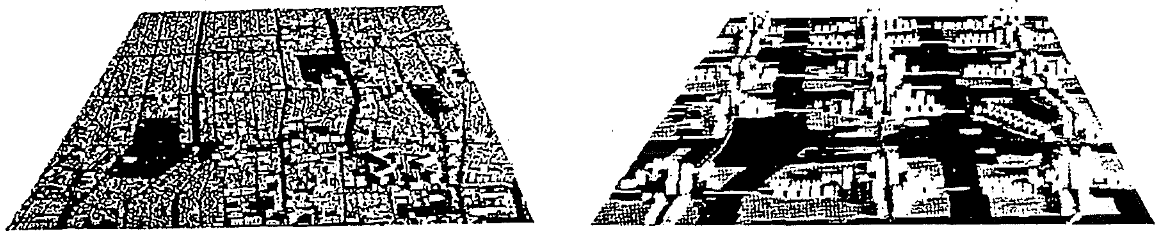
No stable city which is incorporate in the ecosystem is existent to modern city in Japan. Japanese modern cities consisting of huge factories and bedtown are linked with the earth environment through energy, atmosphere and resources. Therefore, when we discuss about the Ecological City, it is necessary to consider how to release impacts on environment. The assignment given to architects is making a city which is as gentle as possible for men and environment.

Heat island and dust dome phenomena are occurred because cities become huge beyond the most suitable size for efficient production and consumption. Namely, it should be an autonomous (or self-supported) city and has closed system to the best of its ability. And underground and skyscraper should be used.

The theme and aim to the Ecological City are to symbiosis relation or moderation between Man and Earth.

Japanese cities are built by land readjustment centered road and urban sprawl from city center to suburban. (shown in Figure 1 (a).)

It is important to make intonation to the existing urban sprawl by keeping transportation joint of urban center high, and middle part low. Also, water and green area should be provided to divide urban area in order to prevent heat island. (shown in Figure 1 (b).)



(a) present (b) future plan

Figure. 1. Shitamachi (old downtown) of Tokyo.

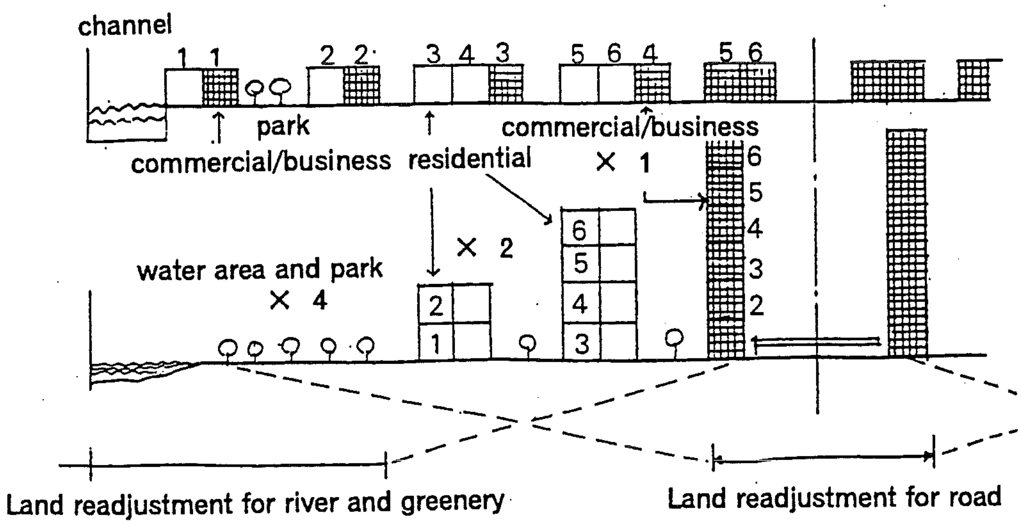


Figure. 2. Land readjustment for road and channel.

For example, as shown in Figure. 2, we proposed land readjustment for water area and greenery against for road.

The points of concept are that;

(1) A city which is aimed at symbiosis relation or moderation between Man and Earth:
(2) A new city what it will be like in the future:
(3) A city which is as gentle as possible for men and environment:
(4) A city which has impacts on environment per a person at a minimum:
(5) An autonomous (or self-supported) city:
(6) A city which has closed system to the best of its ability:
(7) a city which has artifical spaces around water and greenery network:

4. STUDIED CONTENTS UNDER THE ECOLOGICAL CITY SUBCOMMITTEE

Studied contents from 1990 to 1992 are as follows;

(1) to clear the policy of this subcommittee
(2) to clear what the Ecological City is
(3) to show basic data for the purpose of studying the Ecological City
(4) to propose the Ecological City for huge city, Tokyo

As the basic data, the eight items; (1) urbanization: (2) air pollution: (3) water area: (4) planting: (5) energy: (6) heat island: (7) environmental standard: (8) urban facilities, were set up.

By each item, "problems under present conditions", "measures", and "expected effects with measures" were examined to "for Man", "for City" and "for Earth Environment".

Studied contents from 1992 to 1994 are as follows;

(1) to make the environmental standard as academic one which is considered climate characteristics and urban scale for the Ecological City

(2) to propose the Ecological City in Japan

The flow of carrying the environmental standard into effect to build the Ecological City is (1) assessment: (2) taking countermeasures to meet: (3) judgement: (4) confirmation of effect: (5) making a budget: (6) planning: (7) enforcement. The above (1) - (4) should be going to discussed by academy and (5) - (7) should be going to do by administrative organ.

The city classification considered climate characteristics and urban scale for the Ecological City, Japan is shown in Table. 1.

Table. 1. The city classification – considered climate characteristics and urban scale.

climate		
	cool district	Hokkaido
	warm district	Honsyu / Shikoku
	hot district	Kyusyu / Okinawa
population		
	over 1,000,000	
	100,000 - 1,000,000	
	under 100,000	
urbanized situation (floor area ratio)		
	over 300 %	business / commercial
	100 % - 300%	mixed residential and commercial
	under 100 %	residential

The policy of this subcommittee is following. With the urbanization recently, the environmental changes become remarkably, especially, the impacts to urban and earth environment become problems. Aiming at a symbiosis relation or a moderation between Man (the subject) and Earth (the environment).

We think the urban environmental design not to have negative impacts on the earth environment as thoroughly as possible. We propose "the Ecological City" as a new city what it will be like in the future and examine the possibility of its plan. Some proposals are advances to make the action program from both planning and using of city.

ACKNOWLEDGEMENTS

This paper ist based on the ideas and the data discussed in the subcommittee. I arranged it on my own responsibility as a secretary. I wish to thank professor Tosio Ojima and other members.

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URBAN CLIMATE AND CITY PLANNING
(Some examples in Freiburg i. Brsg.)

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ABSTRACT

The need for investigation of the influence of new buildings on urban climate for the set up of development schemes is increasing. Some examples of Freiburg i. Brsg. demonstrate how the influence of new development schemes on urban climate is investigated and how these investigations result in proposals for city planers. Therefore a good cooperation between climatologists, city planers, architects and the municipality is important.

ZUSAMMENFASSUNG

Die Notwendigkeit, den Einfluß von Neubaumaßnahmen auf das Stadtklima abzuschätzen, gewinnt bei Stadtplanern und in der Stadtverwaltung zunehmend an Bedeutung. An Beispielen aus Freiburg i. Brsg. wird gezeigt, wie die Klimasituation erfaßt und die Auswirkungen von Stadtentwicklungsprojekten auf das Stadtklima abgeschätzt werden. Die Ergebnisse dieser Untersuchungen fließen als Empfehlungen in die Bauleitplanung ein. Dabei ist eine gute Zusammenarbeit zwischen Klimatologen, Stadtplanern, Architekten und Verwaltung wichtig.

1. INTRODUCTION

In the last three years many city development projects have been worked out in Freiburg i. Brsg.. For some important projects the planning department ordered climatological investigations to estimate the impact of the new buildings on urban climate. A few selected projects are presented in this paper. It is pointed out in which way climatical aspects were taken into consideration in development schemes. The investigations were carried out by a working group consisting of the *INSTITUT FÜR PHYSISCHE GEOGRAPHIE*, the *TÜV* (Technischer Überwachungsverein) and the *DWD* (Deutscher Wetterdienst).

2. THE CLIMATIC SITUATION OF FREIBURG I. BRSG.

Freiburg i. Brsg. is located in the Upper Rhine Valley on the border to the Black Forest. The altitude reaches from 190 m in the city to 1290 m on the nearby mountains. The average annual temperature is 10.4 °C. In summer temperatures up to 40 °C can occur and therefore Freiburg is the one of the warmest cities in Germany.

Especially in summer during periods of high pressure there is often heat stress for the inhabitants. In autumn and winter during periods of inversion with little air exchange high concentrations of air pollutants can be measured. During radiative nights with weak large-scale motion a nocturnal wind system ("Höllentäler") occurs which developes in the mountains of the Black Forest and furnishes main parts of Freiburg i. Brsg. with colder and less polluted air. In addition to the mountain wind smaller drainage flows from the hills east of Freiburg i. Brsg. lead to better thermal comfort at nighttime especially during summer. These drainage effects are very important for the urban climate of Freiburg i. Brsg.

3. ASSUMPTION FOR THE REQUIREMENT OF A CLIMATOLOGICAL EXPERTISE

Before the planning department gives planning and building permission for a new building project, the influence of the new buildings on urban climate has to be considered. When the authorities claim the need of investigation they commission experts to investigate the influence of the new buildings on urban climate and to summarize the results in a expertise. This expertise describes the climatological situation of the location and the possible influences of the new buildings on urban climate. Furtheron planning suggestions to minimize the negative effects for the urban climate are made.

4. THE CLIMATOLOGICAL EXPERTISE

In order to assess the influence of projected buildings on urban climate the actual climatic situation has to be recorded. For this purpose available longterm data are analysed. In cases when there are no data available for the area of investigation temporary measurement stations are run for a longer period (several months).

For recording the vertical and horizontal distribution of temperature, humidity, wind velocity and wind direction under specific weather conditions, intensive measurement campaigns are organized. The methods of data aquisition are hand measurements, measurement crafts, meteorological ballons and sodar wind profiler.

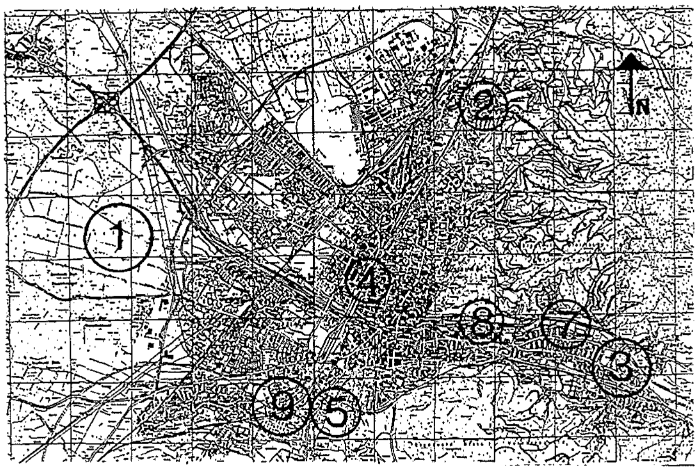
The assessment of the influence of the projected buildings on the temperature, humidity and wind distribution in the area of interest and the adjacent quarters is accomplished using a three dimensional microscale model (RÖCKLE 1990). The model is run for the present and the projected situation. The results of this modelling are compared with the results of field measurements.

All gained information is compiled in an expertise concerning the climatological influence of the projected buildings and hints are given to reduce the negative influence on the urban climate, such as orientating the buildings relative to critical wind directions, limiting the height of the planned buildings and the percentage of sealed surface and improving the thermal comfort by choosing appropriate vegetation like deciduous trees. These suggestions become part of the announcement for the planning of the new buildings. If the negative influence on the urban climate seems to be very serious it is recommended, from the climatological point of view, to draw back the planning and building permission.

5. EXAMPLES

The following climatological expertises were completed by the working group in Freiburg i. Brsg. (Fig.1):

1. Rieselfeld (new suburb for estemately 9000 Inhabitants) 1991
2. Zähringen - Höhe (new housing estates) 1991
3. Kappler Straße (new blocks of flats) 1992
4. Hauptbahnhof (new skyscraper for flats and offices) 1992
5. Schlierberg (new housing estates) 1992/93
6. Waltershofen - Gießental (new apartment houses) 1992/93
7. Sportclub Stadion (extention of a stadium) 1993
8. Hirzberg (new high rise flats) 1993
9. Vauban Kaserne (new quarter on the area of old barracs) 1993



1. Rieselfeld
2. Zähringen - Höhe
3. Kappler Straße
4. Hauptbahnhof
5. Schlierberg
6. Waltershofen - Gießental (westerly of the mapped area)
7. Sportclub Stadion
8. Hirzberg
9. Vauban Kaserne

Figure 1: Completed climatological expertises in Freiburg i. Brsg.

Railway station

It was projected to build a new station as a skyscraper about 30 m high and 200 m long with two 70 m high towers on each edge.

The climatological influence of this building on the urban climate of the western districts is investigated. The wind was modelled in microscale with different wind directions. From the climatological point of view the projected shape of the building is unfavourable because the closed front of the building blocks the "Höllentäler", so that the western districts are less ventilated. As a result of the investigation it was recommended to leave three 8 to 14 meter wide gaps in the building front so that the wind can pass through (Figure 2). The resistance of the building with gaps is reduced by 75 percent compared to the building without gaps.

Figure 2: Projected Railway Station (newspaper report).

Rieselfeld (projected new suburb with 3900 flats for 9000 inhabitants)
The analysis of the climate was aiming on the interaction between the projected area and the adjacent quarters. For that purpose the climatic relevance of the 'Rieselfeld' for the quarters located east of the projected area was investigated. Another aim was to give hints for the orientation of the buildings in order to avoid negative influences on the climate of the new suburb. An important aspect is the ventilation during radiative summer nights and the question if the mountain wind from the Black Forest reached the projected area.
In addition to the analysis of existing data five temporary climate measurement stations were run and two intensive 24-hour measurement campaigns were carried out. The horizontal distribution of temperature, air humidity, wind direction and wind velocity was recorded by two measurement crafts and several mobile hand measurements. The vertical distribution of wind was recorded by a sodar.
As a result it was found out that at night there is no significant air flowing from the 'Rieselfeld' to the adjacent quarter. Instead, the 'Höllentäler' (ESE wind) dominates the nocturnal wind situation on the 'Rieselfeld'.
In periods of high pressure northern winds dominate during daytime. Strong south westerly winds occur under cyclonic weather conditions.
Planning suggestions are made for the structure of buildings and streets concerning their orientation relative to the critical wind directions. Figure 3 shows the model of the new suburb. Most of the planning suggestions are realized in the model. There is open space to the north towards the weak northern winds. The easterly winds can penetrate into the new suburb along the main roads. The closed house fronts and the forest in south west of the quarter block the strong south-westerly winds.

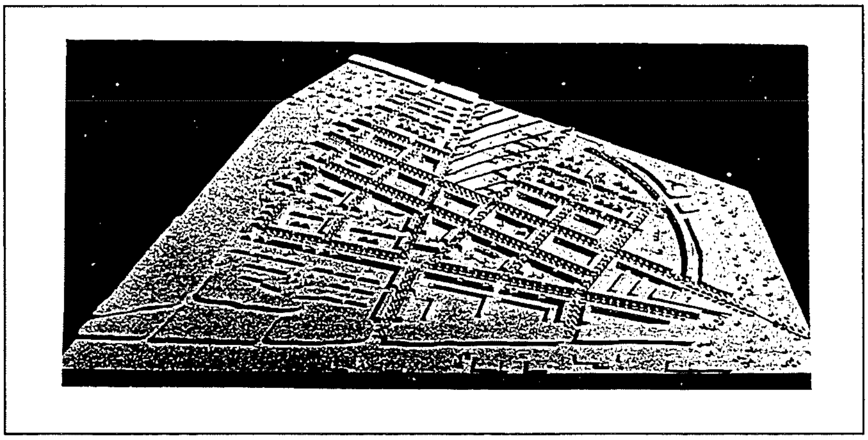


Figure 3: Projected new suburb 'Rieselfeld'.

Kappler Straße (projected high rise flats)
In the 'Kappler Straße' several blocks of flats are projected. The influence of the planned buildings on the dynamics of the nocturnal wind system ('Höllentäler') and the ventilation of the western districts was investigated. Two climatologic measurement stations were run for several months. The wind was modelled and the results of the model (Figure 4) are compared with results of field measurement campaigns.
As a result of the investigations hints were given to the planer to reduce the height of the buildings so that the influence on the 'Höllentäler' will be minimized. The percentage of the sealed surface should be reduced in order to minimize the heat stress in sommer.
The proposals made in the climatological report were realized in the conception of the new high rise flats.

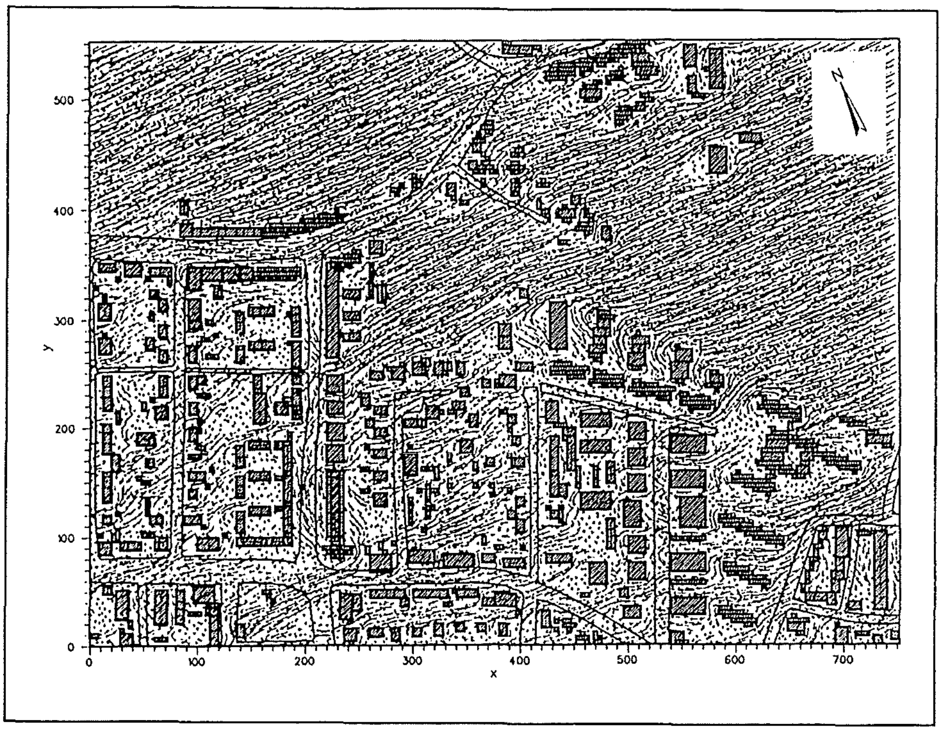


Figure 4: Modelling of east wind (windspeed 1.5 m/s) 'Kappler-Straße Nord' for the planning area

6. CONCLUSIONS

The need for investigation of the influence of new buildings on urban climate for the set up of development schemes is increasing. The proposals of the climatologists are often considered by the city planners, but the climatological aspect is only one demand among others on new building projects. Therefore a good cooperation between the climatologists, the municipality, architects and city planers is important.

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CONTRIBUTIONS OF SEA BREEZE AND NATURAL COVERINGS TO AIR TEMPERATURE DISTRIBUTION IN A SEASIDE CITY

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ABSTRACT

For the urban climate, natural ventilation by the sea breeze plays one of the most important roles in improving the thermal environment, particularly in hot and humid summer in a seaside city. The cooling effects of the sea breeze is notably greater at its time shift in direction from the land breeze to the sea breeze. When the wind is gentle or wind blows from the land, the air temperature in the center of the city is the highest, contrasted to that in the suburbs with varied vegetation where the air temperature is lowest. When the wind blows from the sea to inland, the sea breeze carries the hot air from the center of the built-up zone to its leeward side. Mitigation of the urban heat requires consideration of climatic effects in environmental design for the efficient usage of natural cooling resources and natural covering as a significant, integral part of urban planning and site selection.

1. INTRODUCTION

Urbanization is characterized by high-rise, crowed buildings and paved ground which replace many natural materials of water, open space and vegetation. Urbanization also occurs without an overall comprehensive urban plan and its structures disrupt air flow patterns and their resulting cooling effects. Thus, urbanization changes the temperature and air flow patterns of local climates into an "urban climate" characterized by an increase of air temperature, a decrease of wind speed and so on[1)].

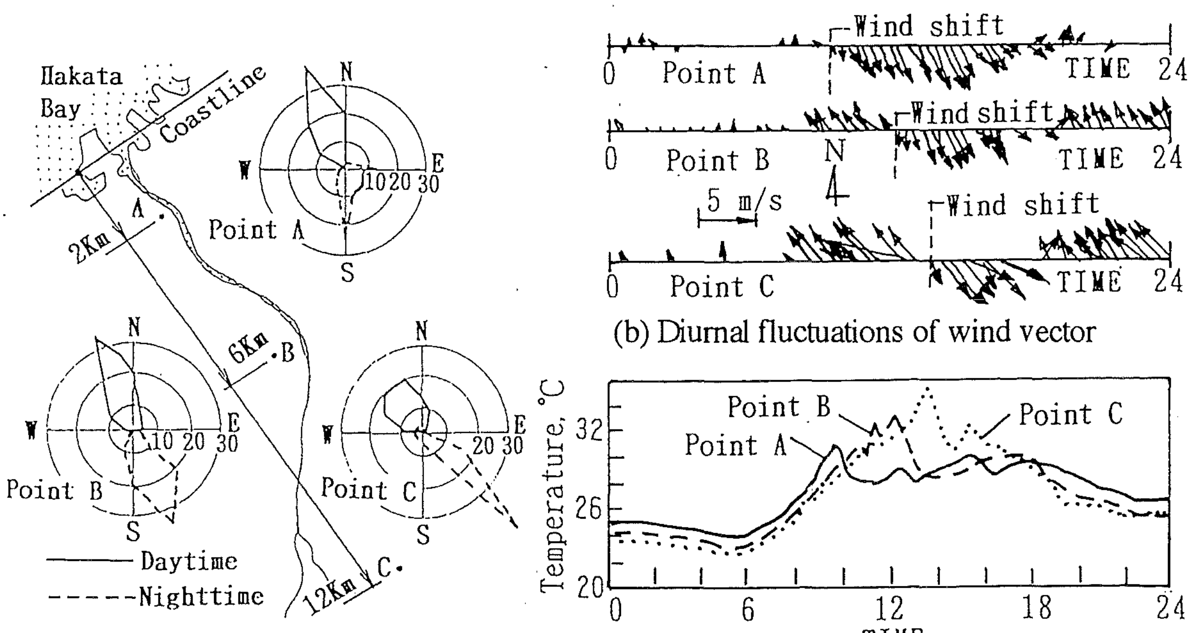
The sea breeze is provided in the summer daytime and becomes a natural cooling resource to improve the urban thermal environment in a seaside city[2)]. There are few studies to examine its cooling effect quantitatively from a viewpoint of the urban climate. Water and vegetation are the most readily available natural materials for modifying the climate. This paper presents the survey results of thermal cooling created by these natural resources in summer in an urban area.

2. COOLING EFFECTS OF THE SEA BREEZE

Wind direction, wind speed and air temperature were observed simultaneously in summer at three stations located almost in a line to the direction of the sea breeze[3)]. The distances from the coastline to three stations were about 2km, 6km and 12km, respectively. Propeller-type anemometers and vanes were used to observe wind speed and wind direction. Air temperatures were measured by thermo-couples with sun-shades at 10-minute intervals.

Windroses at each point are shown in Figure 1 (a). Wind blows from the sea in the daytime and the prevailing wind directions from the sea and from the land at each point are almost parallel to the line linking the three observation points.

A sample of the daily fluctuations of wind vector and air temperature is indicated in Figure 1 (b). The wind shift from the land breeze to the sea breeze is delayed at the landward station. The air temperature falls noticeably when the wind shifts from the land breeze to the sea breeze, and remains low while the sea breeze is blowing. The maximum temperature is lowest at the station nearest to the coast line.



(a) Location of three observation stations and their windroses

(c) Diurnal fluctuations of air temperature

Figure 1. Windroses and diurnal fluctuations of wind vector and air temperature in summer at three stations located almost in a line to the direction of the sea breeze.

3. EFFECTS OF LAND-USE AND WIND ON AIR TEMPERATURE DISTRIBUTION

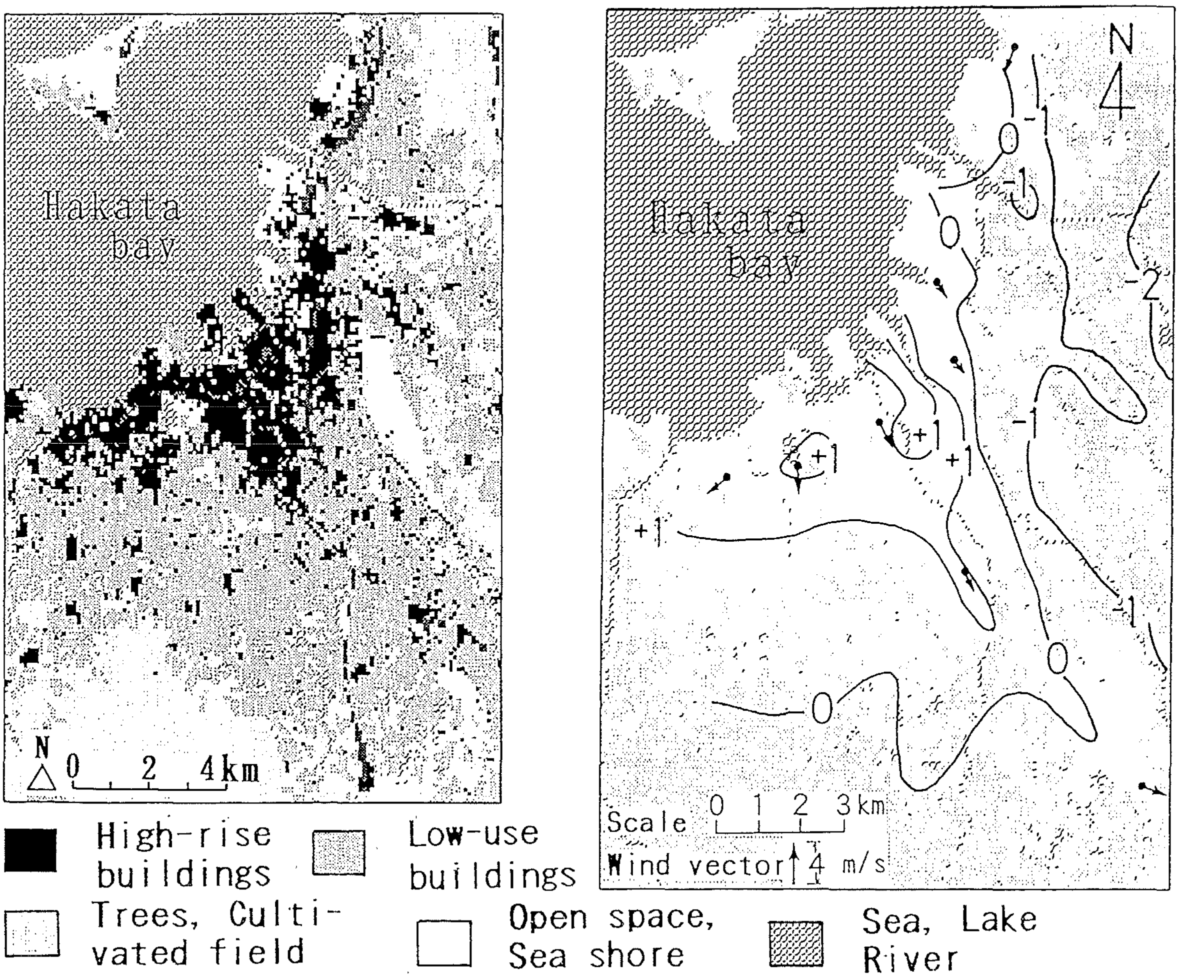
Fukuoka City faces Hakata Bay and its environment forms three zones: the high-rise buildings zone in the center, the low-rise buildings zone around the former and the vegetation and cultivated fields zone surrounding these two, as shown in Figure 2 (a). Air temperatures were measured by thermistor thermometers with sun-shades mounted on eight cars at 06:00 in the early morning and at 14:00 in the daytime. Numbers on the contour lines are the normalized air temperatures calculated by the following equations;

$$T_i = \frac{t_i - \langle t \rangle}{\sigma}, \quad \langle t \rangle = \frac{1}{n}\sum_{i=1}^{n} t_i, \quad \sigma = \left\{ \frac{1}{n}\sum_{i=1}^{n} (t_i - \langle t \rangle)^2 \right\}^{1/2}$$

where, T_i =normalized temperature, t_i =air temperature at point i, n=number of measurement points (958).

The wind vectors at eight points are represented by the arrows. In the early morning, mean wind speeds at these eight points are less than about 2 or 3m/s and the contour lines of normalized air temperature correspond well to the distribution of land-use. That is, the air temperature in the center of the city, where the prevailing ratio of high-rise building is the highest, contrasted to that in the suburbs with varied vegetation where the air temperature is lowest, as indicated in Figure 2 (b)[4].

The investigation area was divided into 1km square grid and the measured values of air temperature were averaged in each cell. The ratios of the natural covering such as trees, cultivated fields and water surfaces of lake, river and sea were calculated in each cell of the



(a) Distribution of land-use (b) Distribution of air temperature

Figure 2. Distributions of land-use and air temperature under the calm wind.

1km square grid to examine the relation to the air temperature. It is clear that the larger the natural covering, the lower is the air temperature (Figure 3).

Air temperatures were measured again to investigate the wind effect on its distribution in the narrower area shown in Figure 4 (a). In the early morning when the wind blows from the land, the air temperature between the coast line and 4km inland is high and becomes lower according to the distance from the coast line (Figure 4 (b)). In the daytime when the wind blows from the sea to inland, the high air temperature region moves from the center of the built-up area to the leeward side of land (Figure 4 (c)). That is to say, the sea breeze carries the hot air from the center of the built-up zone to its leeward side[5].

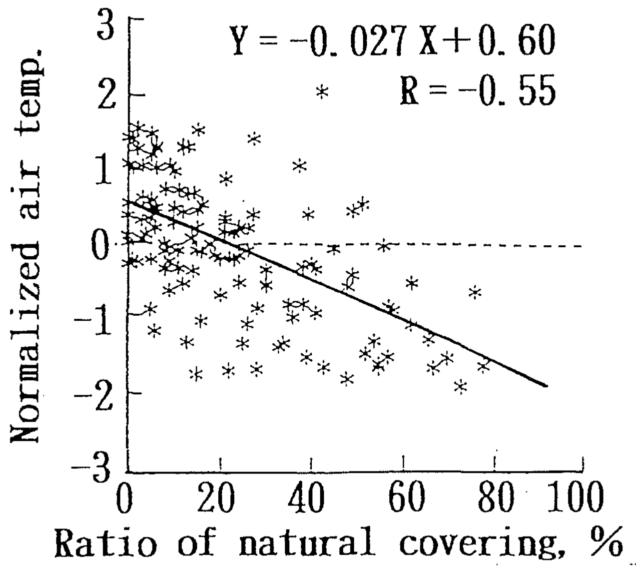
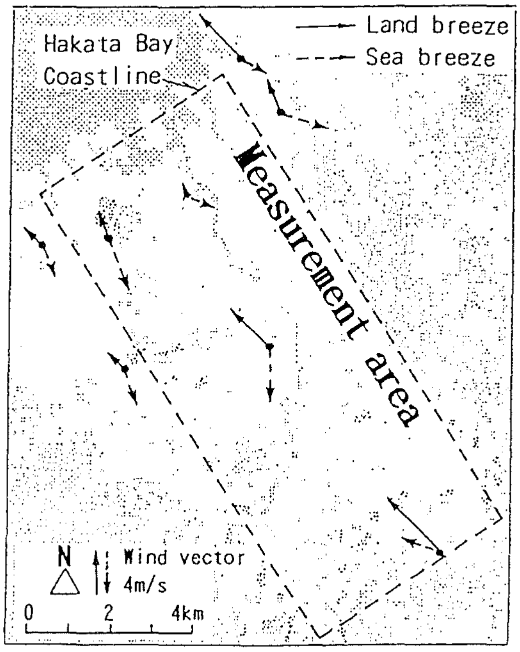


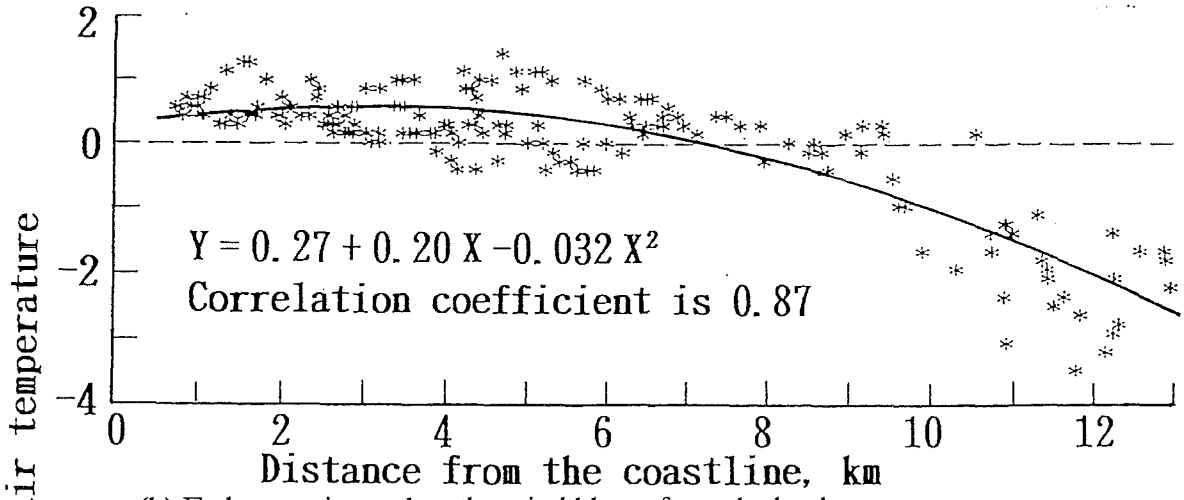
Figure 3. Relation between natural covering ratio and average air temperature in 1km square cells under the calm wind.

4. COOLING EFFECTS OF A RIVER

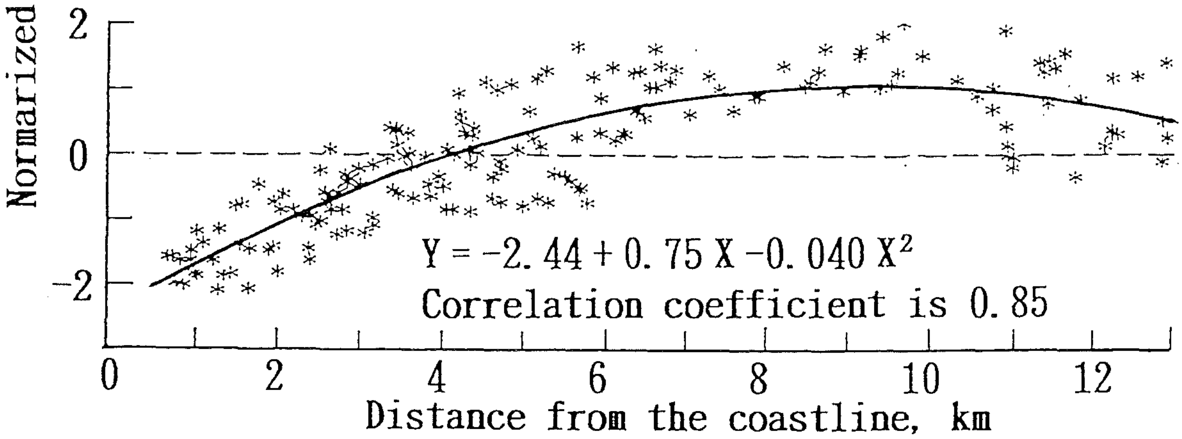
The Naka River, which is about 100m wide, flows from SE to NW through the downtown area of Fukuoka City. One of the streets, with a width of about 40m, is nearly parallel to the Naka River for a distance of about 400m. The street crosses the river at a point about 6km upstream from its estuary. Measurement points were set at the coast and at the cross point. Between these points, there were four additional pairs of measurement sites each on the river and on the street (Figure 5 (a)). The measurements were carried out on a clear day in August[6]. When the sea breeze blows, the wind speed increases more over the river than over the street, and the wind direction above the river remains fairly constant while the wind direction over the street becomes irregular (Figure 5 (a)). When



(a) Distribution of wind vector

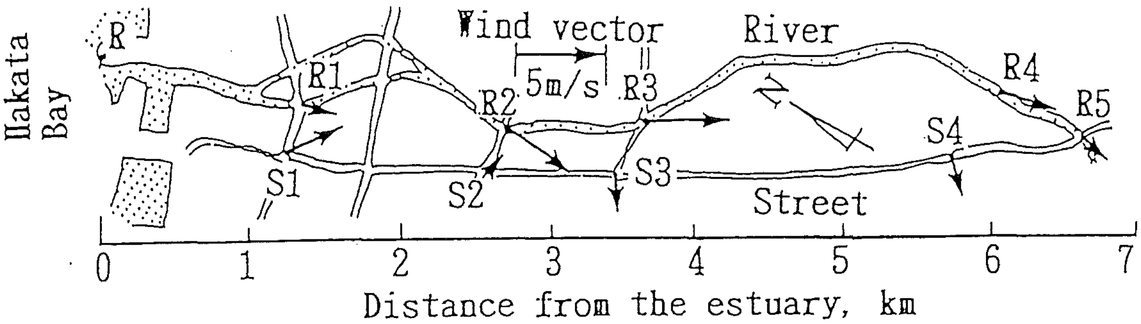


(b) Early morning, when the wind blows from the land

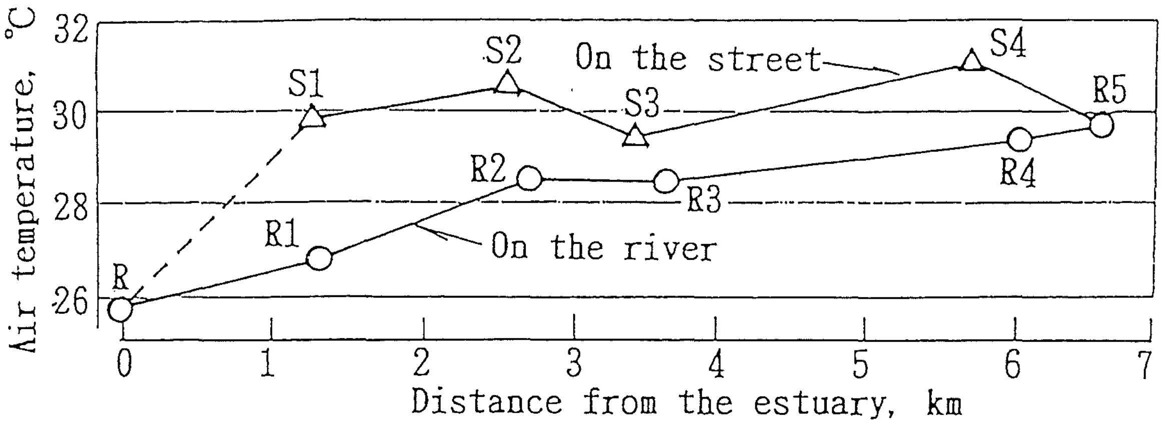


(c) Daytime, when the wind blows from the sea

Figure 4. Comparison between the air temperature distribution according to the distance from the coast line in the early morning and that in the daytime.



(a) Measurement points and wind vectors



(b) Distributions of air temperature

Figure 5. Comparison of the distributions of wind vector and air temperature along the river with those along the street at 13:00 on the clear summer day.

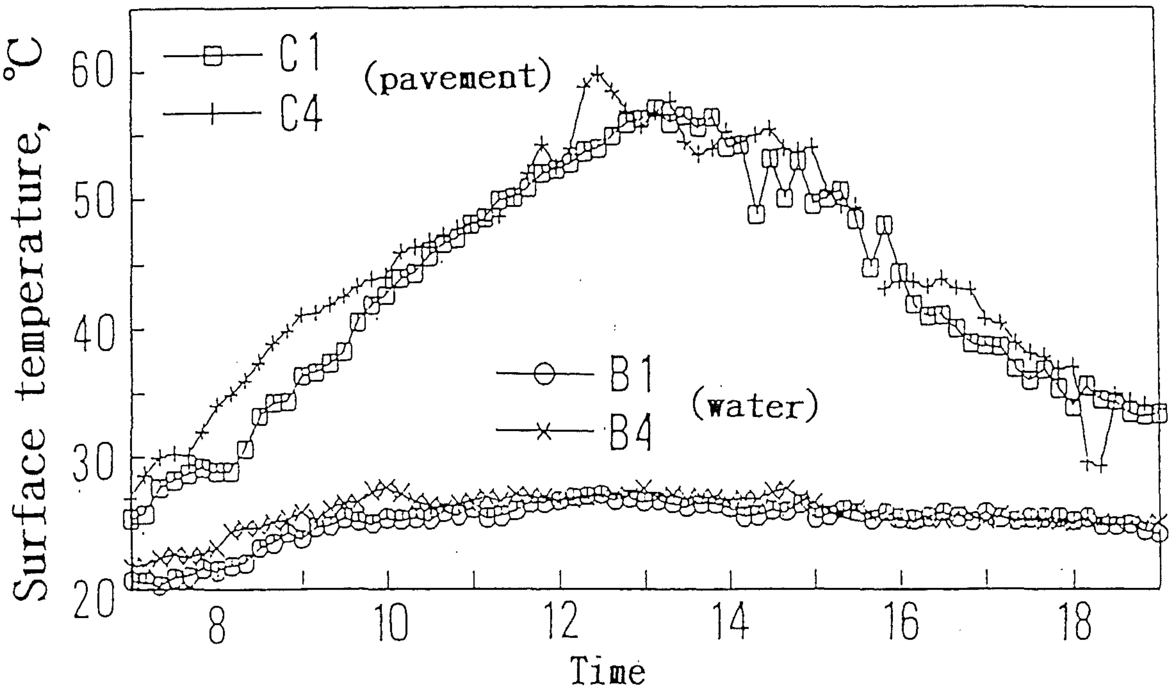


Figure 6. Comparison between the surface temperatures of the river water and those of the asphalt pavement.

the intensity of the sea breeze increases, the air temperature above the river is clearly lower than that above the street and increases gradually from the estuary upstream in the daytime (Figure 5 (b)). This indicates that blowing inland, the cooler air of the sea breeze above the river is mixing with nearby hot air and cools the neighbouring area of the river.

The fluctuations of surface temperatures on the river water and the on the street are shown in Figure 6. The surface temperature of the river water is lower than that of the asphalt pavement of the street during the daytime. Water surface temperatures fluctuate gently between 21℃ and 27℃ and, in contrast, the surface temperatures of the pavement in the sunshine change from 25℃ at 07:00 to 60℃ at 13:00 according to the amount of solar radiation. The difference in surface temperature between the water and the pavement reached more than 25℃ at about 13:00.

5. CONCLUSION

(1) The cooling effect of the sea breeze is notably greater at its time shift in direction from the land breeze to the sea breeze.
(2) When the wind is gentle, a high temperature zone is observed in the center of the built-up area where the coverage of the ground surface with high-rise building is dominant.
(3) The sea breeze carries the hot air from the center of the built-up zone to its leeward side.
(4) A river is a useful open space to introduce the sea breeze deep into the urban area.

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WASTE HEAT FROM SPACE COOLING SYSTEMS - DO THE COOLING SYSTEMS FOR BUILDINGS PROMOTE THE URBAN HEAT-ISLAND ? -

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ABSTRACT

To evaluate the effects of waste heat discharged from space cooling systems on the heat-island phenomenon, we must divide the waste heat into sensible and latent heat. Sensible waste heat from the space cooling systems is increasing in Japanese city. It is shown that the regulation of the sensible heat discharge is one of the important policies to diminish the impact on urban heat-island.

INTRODUCTION

Space cooling system keeps the interior of buildings comfortable in hot climate. However, since it just moves heat from the interior to the exterior, it may be a popular view that the outdoors becomes hotter and the heat-island becomes stronger by the increase of the space cooing systems. The situation is shown in Fig. 1.

But It is not sufficient to evaluate the effects of the waste heat from the space cooling system on the heat-island phenomenon by such the simple manner. To evaluate the effects, we must divide the waste heat into sensible and latent heat at least (Fig. 2), because the balance of the sensible heat (ΔQ_s) raises the atmospheric temperature, and that of the latent heat (ΔQ_L) raises the atmospheric humidity. ΔQ_s and ΔQ_L depend on the type of heat-exchanger through which the waste heat is transfered from the cooling systems to the atmosphere.

ROUGH ESTIMATION OF ΔQ_s AND ΔQ_L

Wet-type heat exchanger, such as evaporative cooling tower, discharges most of the waste heat in the form of latent heat. On the other hand, dry-type heat-exchanger discharges all of the waste heat in the form of sensible heat. In the case of no indoor heat generation, rough estimation for the heat budget is shown in Fig. 3(a) and (b). Since the balance of sensible heat for wet-type is negative as shown in Fig. 3(a), the space cooling systems with it lower not only the indoor temperature but also the outdoor one. It acts just same as the plant does. On the other hand, the balance of sensible heat for the dry-type is positive and the balance of the latent heat is negative as shown in Fig. 3(b),the space cooling system corresponds to a converter of heat from latent heat to sensible heat. This type must promote the heat-island phenomenona.

PRECISE SIMULATION OF THE REPRESENTATIVE COOLING SYSTEMS

Five representative space cooling systems, which are shown in Table 1, were analyzed to get time-series change of the waste heat. Computer simulations were conducted when each system is adopted to a standard office building located in Osaka, Japan. The waste heat is divided into four parts, ①sensible and ②latent heat through building walls, and ③sensible and ④latent heat from cooling system. The results are shown in Fig. 4(a), (b), (c), (d) and (e). The results coincide with the above mentioned results for the rough heat budget analysis. System 4 is the most critical one for the promotion of the heat-island.

The authors named the heat exchanger "interface between the space cooling system and the environment" and give the prominence to it.

CONTRIBUTION OF THE WASTE HEAT FROM SPACE COOLING SYSTEMS IN URBAN REGION

Heat-island phenomena are caused by the sensible heat transfered from the earth surface to the urban atmosphere. To evaluate the fraction of the sensible heat in whole transfered sensible heat, a case study was done at OBP (Osaka Business Park: newly developed central business zone of Osaka). Out-look of OBP are shown Fig. 5. The composition of the earth surface are shown in Table 2. The other outlines of OBP are shown in Table 3. The sensible and latent heat transfered from the earth surface to the atmosphere were estimated by computer simulation. The calculated results are shown Fig. 6. Fraction of the total (sensible and latent heat) heat, which is discharged from the space cooling systems, is about 55 % of total heat including the contribution of the solar irradiation. It became clear that the control of the waste heat from the space cooling systems is one of the most important policies to diminish the impact on the heat-island phenomena in densely concentrated city.

TREND OF THE SENSIBLE WASTE HEAT DISCHARGED FROM THE SPACE COOLING SYSTEMS IN OSAKA CITY

Sensible heat from the space cooling systems is increasing by the following five factors. (1) Number of Buildings is growing. (2) Cooling load per unit floor area is growing. (3) The share of the dry-type is growing. (4) Air-conditioned area is growing. The effect of the each factor was evaluated by analyzing several informations. Maps of sensible heat discharged from the space cooling systems are produced for 1977 and 1985. They are shown in Fig. 7(a) and (b). The size of the each mesh is 500 m • 500 m. It is shown that the sensible heat is increasing with time.

The total amounts of the waste heat from the space cooling systems in Osaka city for each type of buildings are shown in Table 4.

CONCLUDING REMARKS

Waste heat discharged from the space cooling systems is more than 50 % of total heat transfered from the earth surface to the atmosphere in the densely concentrated city. The fraction of the sensible heat is increasing with time. The regulation of the discharge of the sensible waste heat is one of the most important policies to diminish the impact on the heat-island.

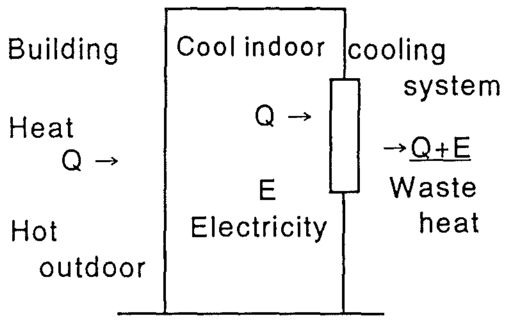
PROPOSAL

(1) Using a cooling system with both dry- and wet-type heat exchanger may be a good idea.
The dry-type may be used for day-time and the wet-type for night-time.

(2) Regulation for the discharge of the sensible heat is recommended.

(3) Financial support is required for wet-type system.

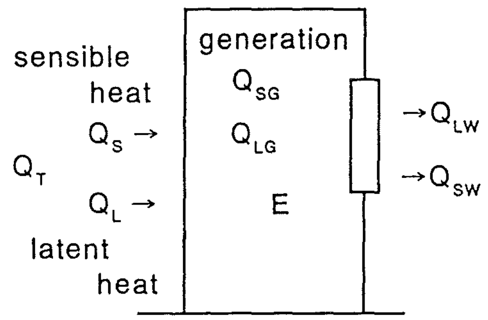
(4) To make a guideline for an allowable equivalent total waste heat discharge
Q_{ETW} (= $Q_{SW} + W \cdot Q_{LW}$) . Evaluation of W in the equation is needed.



The balance(= Q+E - E)

warms the atmosphere.

Figure 1. Simple heat budget



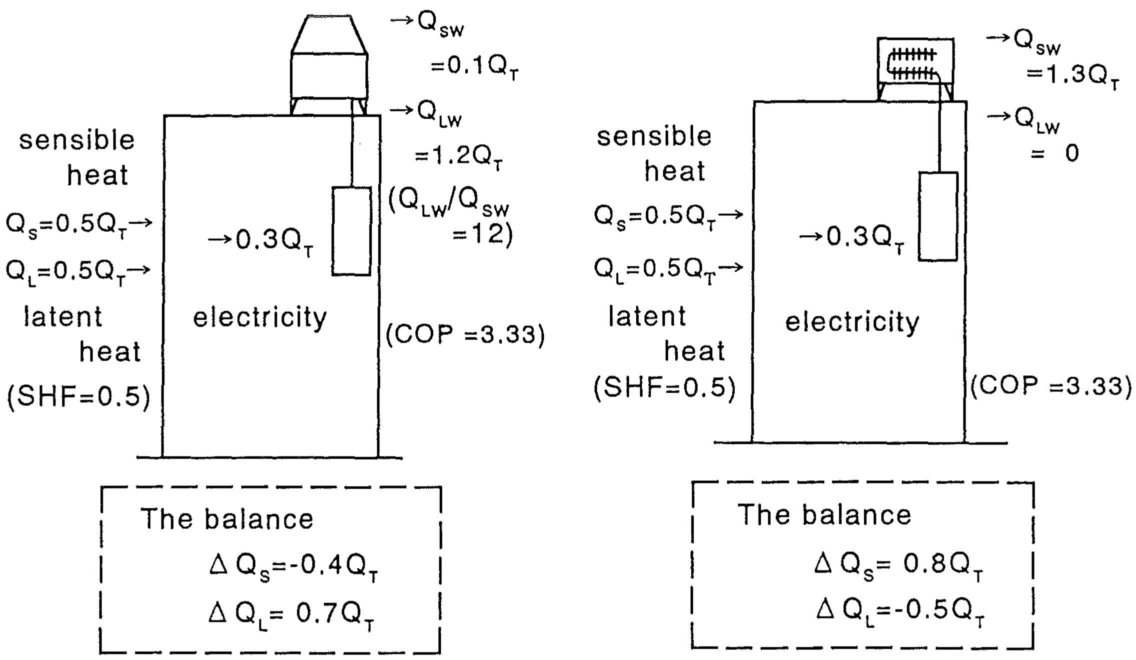
$\Delta Q_S = Q_{SW} - Q_S$

increases the atmospheric temperature

$\Delta Q_L = Q_{LW} - Q_L$

increases the atmospheric humidity

Figure 2. Correct heat budget



(a) Wet-type (b) Dry-type

Figure 3. Heat budget for space cooling

Table.1 Representative space cooling systems

	No. Composition of cooling system
1	electric turbo refrigerating machine + evaporative cooling tower
2	gas absorption refrigerating machine + evaporative cooling tower
3	air cooled heat-pump
4	air cooled heat-pump + thermal storage tank
5	air cooled heat-pump + thermal storage tank + heat recovery turbo refrigerating machine

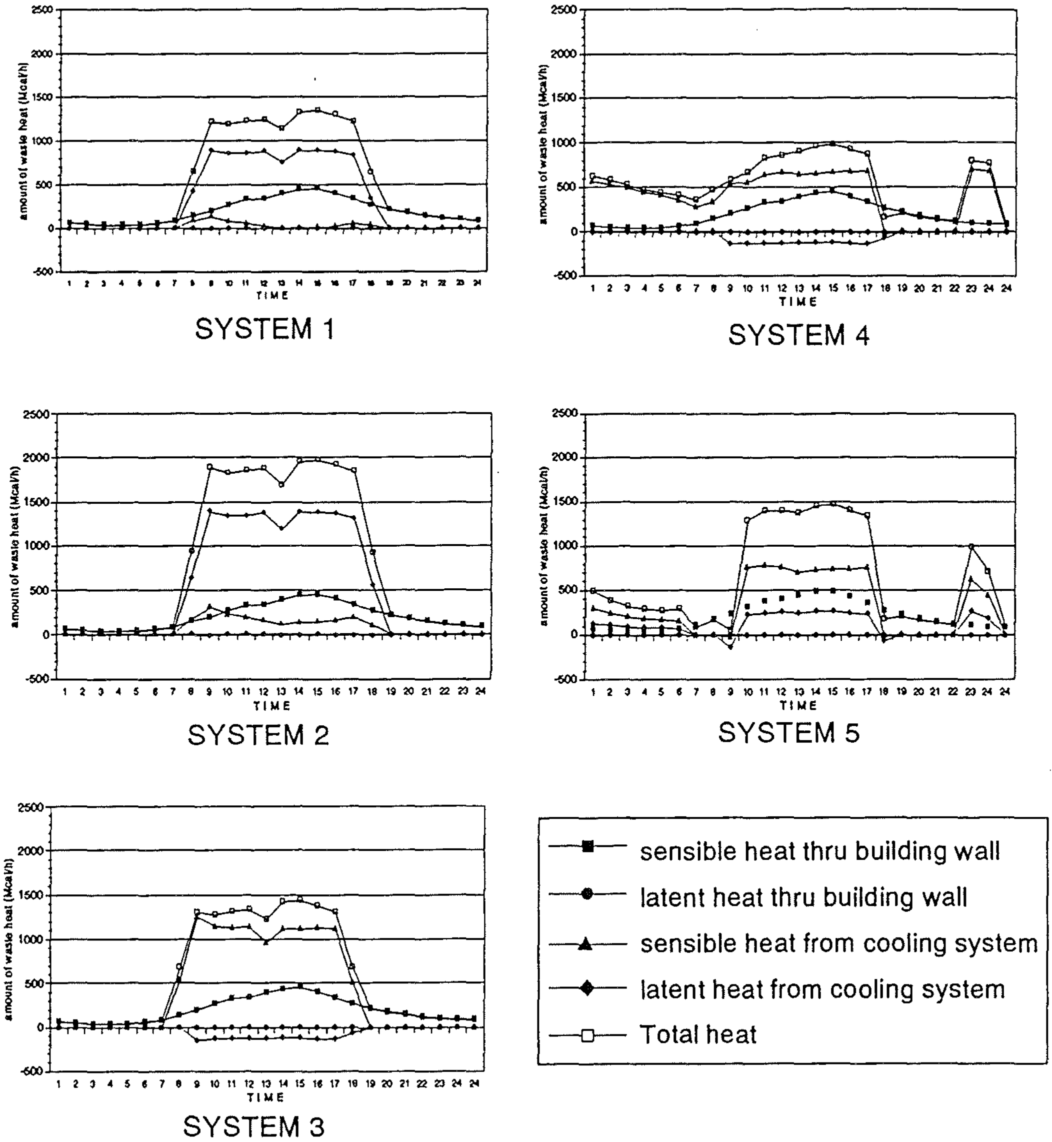


Figure 4. Time-series change of Waste heat in August

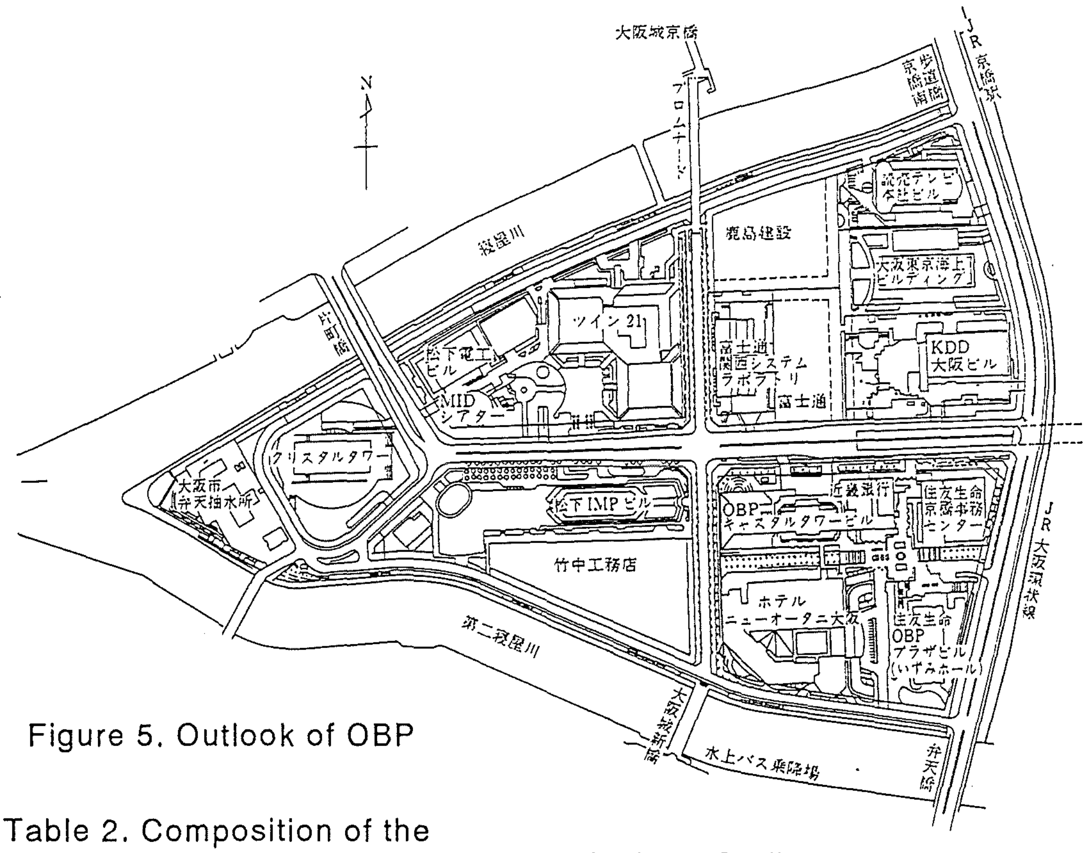


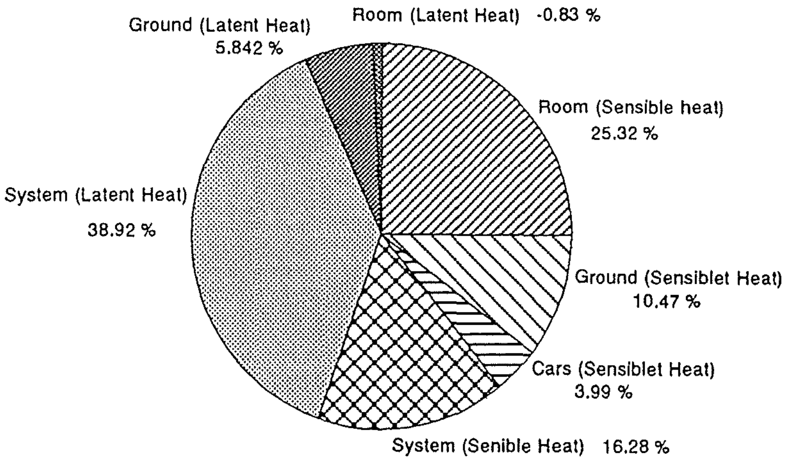
Figure 5. Outlook of OBP

Table 2. Composition of the earth surface in OBP

Buildings	6.5 ha
Concrete surface	8.4 ha
Asphalt earth surface	7.2 ha
Bare earth surface	0.6 ha
Grass surface	0.6 ha
Covered by trees	3.3 ha
T o t a l	26.6 ha

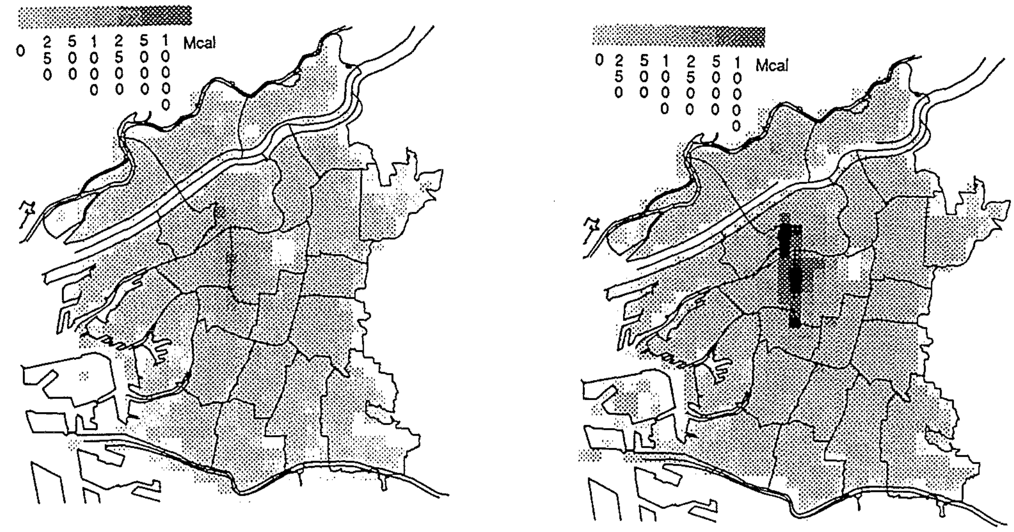
Table 3. Outlines of OBP

Total floor area of buildings	80ha
Day-time population	150,000



Total amount of waste heat : 960Gcal/day

Figure 6. Composition of heat transfered to the atmosphere in August



(a) 1977 (b) 1985

Figure 7 Maps of sensible waste heat from space cooling systems in OSAKA in August

Table 4 Change of total waste heat from space cooling system between 1977 and 1985,in Osaka City,in August (unit:Mcal/month)

Buildings	latent waste heat			sensible waste heat		
	1977	1985	ratio*	1977	1985	ratio*
residence	0	0	-	187140	215080	1.15
office	202800	165710	0.82	85520	216940	2.54
shop	172700	183240	1.06	66600	96700	1.45
factory	444170	198230	0.45	136590	173740	1.27
school	3160	3940	1.24	3540	2910	0.82
hospital	13140	15870	1.21	606	9570	1.58
others	372520	341700	0.92	139500	364910	2.62
total	1208490	908690	0.75	624950	1079850	1.72

remark * : ratio means (1985/1977)

KOBE ECOLOGICAL ARCHITECTURE STARTED THE OUTLINE OF PROJECT AND AWAITING SOLUTIONS

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This paper was written about the outline of a project for ecological architecture of Kobe. The project includes defining the basic concept, editing the manual for ecological architecture, workshop for designing ecological architecture, model constructions, and publishing the leaflet for public relations.

The project had begun from 1993 leading Kobe municipal government, and the project is continuing now in 1994. At the beginning of the project, city government planned to edit a convenient and simple manual for architecture. But before editing the manual, it was necessary to define the ecological architecture in Kobe. And going the project ahead, the necessity of public relations on the ecological architecture rose up to people around us. So we prepared a workshop as a event for enlightening. People attended the workshop had strongly felt the importance of considering about the ecological system and ecological manner for architectures.

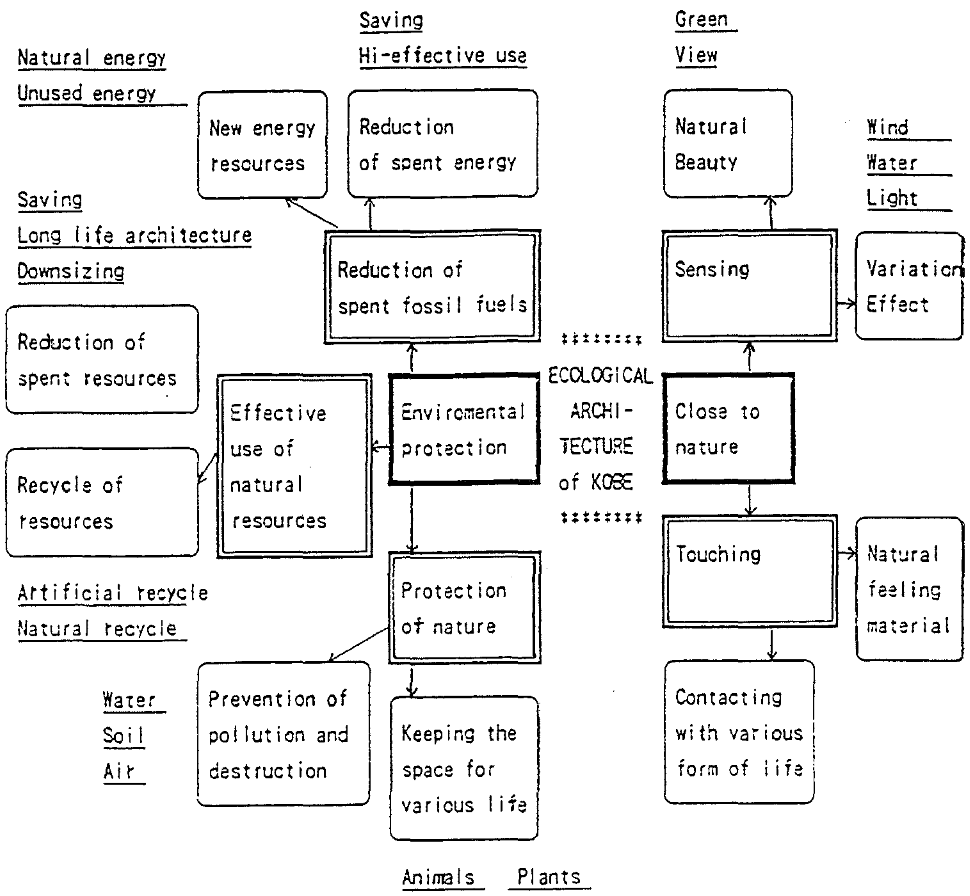


Fig.1 Basic Concept of Kobe Ecological Architecture

Basic concept for presenting the manual is offer from "Kobe Ecological Architecture Development Team", consisted as a study group. The team had discussed for over a half of year, and offer the concept as Fig.1.

The key words are from 2 sentences.
1) Protecting the natural environment. (Low Impact)
2) Close to the nature. (High Contact)

But the most important concept is written by another sentence,"take advantage of natural phenomena". Because Kobe city rarely has both hills and sea, and plenty of woods as a big city that has over one million population. Added to this, the region around Kobe has sunny comfortable climate. Another noticeable point is importance to make the natural or nature-like spaces in architectures (and cities) in order to remember the goodness of the nature in mind of people, and to keep our body naturally healthy.

The ecological architecture manual was edited 2 main chapters. One is written along the stages of an architecture. Those are site-planning, building- planning, equipment-planning in buildings, and constructing. Over than 70 menus including saving-energy, recycle, poisonless or low impact methods are introduced for basic planning of architecture. Another is written by the differences among some use of building such as a welfare center, a school, or an apartment house. The remarkable point is concerned with energy spent. A school does not spend much energy because of their non air-conditioning. Therefore we must consider about saving-energy in the case of residences.

The study group also contributed to the workshop as a facilitator. The workshop was held for designing of the ecological architecture model constructions. 2 of those constructions were picked up. Both are welfare-centers for limited district (facilities for welfare and communication in the districts around them). The study group asked the delegates from districts around the 2 centers to attend the workshop and offer their own opinions in the discussion with specialists and city servants. Many proposal were shown in the concluding table meeting. And most of them were accepted to the actual plans of the centers. (Shown in Figure 2, Figure 3)

In August 1994, city government published color-leaflet for public relation on "Kobe Ecological Architecture Project". That is for ordinary people not as the manual for architects.

Yet we have some awaiting solutions. One of most difficult problems is seemed to be how to appreciate the effect of taking the advantage of natural phenomena. For example, in our equipment planning of public buildings, we do not have any simple method to measure the load of air-conditioning by using the cooling effect of natural wind blowing. In addition to this, we have few useful map of natural resources such as wind, sunshine, greens. But to solve the problems, for example, examining the result of model-constructions is planned after completion of the constructions. From the activity of the project. The following results were obtained:

1) Kobe has good natural condition for ecological architecture, and we must take the opportunity.
2) Workshop event is important and effective for public relations about ecological lifestyle to people who use the facilities made in ecological manner.
3) We must develop how to appreciate the advantages of natural phenomena from now on.

I wish to express my special thanks to Mr. Hiroshi Miyazaki for his arrangement to write this paper. My thanks are also due to the members of „Kobe Ecological Architecture Development Team“.

Model Construction of Ecological Architecture (1) (will be finished 1994.12)

Onoe-district Welfare center Asahi-dor i2chome, chuo	Construction	Reinforced wall and frame const.
	Lot area	333.98 m^2
	Building area	240.20 m^2
	Total floor area	264.18 m^2
	Number of stories	2

- Ecological Manner and Why we do so. -
This center is in the central city of Kobe. People in Onoe-district hope greeny space.

[Selected ideas from Eco-Workshop]

- Plants as Roof-Garden etc. On roof, on walls, on ground of inner court — (Solution for heat irland, close to nature)
- Using rain water, saving in tanks — (Reduction of amount of water spent)
- Recycle use of warm air in upper part — (For reduction of heating load)
- Open pilotis — (Solution for heat irland by ventilation)
- Opening for natural daylighting — (For reduction of lighting load)

[Ideas from designers]

- Wall and frame construction with fill-up concrete blocks — (For reduction of using tropical forest wood)
- Wide and deep eaves — (For reduction of cooling load by protecting summer solar radiation)
- Selecting finish material — (Recycle, prevention of pollution)

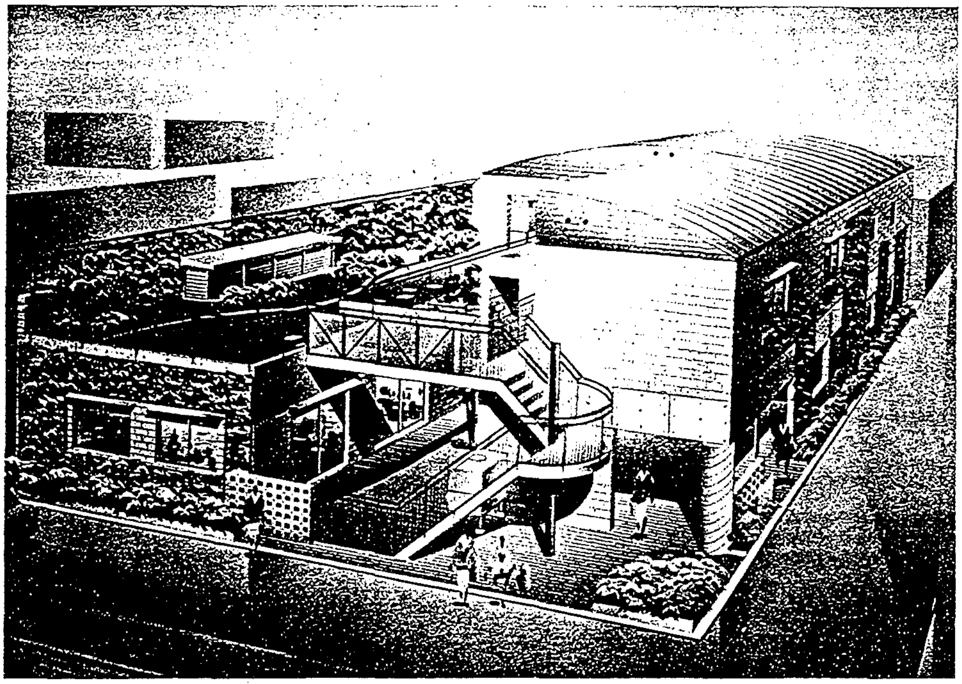


Fig.2 Model-construction „Onoe district welfare center“

O Model Construction of Ecological Architecture (2)

Ougo-district	(The construction will be finished Jan.1995)		
Welfare center & child-care center	Construction	Reinforced concrete construction	
	Lot area	817.51 m^2	
Okeyakakiuchi, ougo-cho, kita	Building area	522.94 m^2	
	Total floor area	522.94 m^2	
	Number of stories	1	

- Ecological Manner and Why we do so. -

We hope to use the effect of natural environment in such suburban area.

[Selected ideas from Eco-Workshop]

- Receive wind from the west by V-form plan (For reduction of cooling load by natural wind)
- Wide and deep eaves (For reduction of cooling load by protecting summer solar radiation)
- Many species plants in a garden (Keep natural condition around site)
- Tall trees along the westside windows (Pretection against cold west wind in winter and summer solar radiation)
- Using water permeable material (Keeping natural water circulation)
- Using rain water for plants and pond. saving in tanks (Reduction of amount of water spent)

[Ideas from designers]

- Selecting finish material (Recycle, prevention of pollution)
- Ventilation and using warm air by heat chimney (For reduction of cooling and warming load)
- Concrete forming panel made of heat insulating material (For reduction of using tropical forest wood)
- Ventilation fan moved by using a solar battery (For reduction of cooling load)
- Pair-glass windows with wooden frame (For reduction of cooling and heating load)
- Heating by solar hot-water system (For reduction of using fossil fuels)

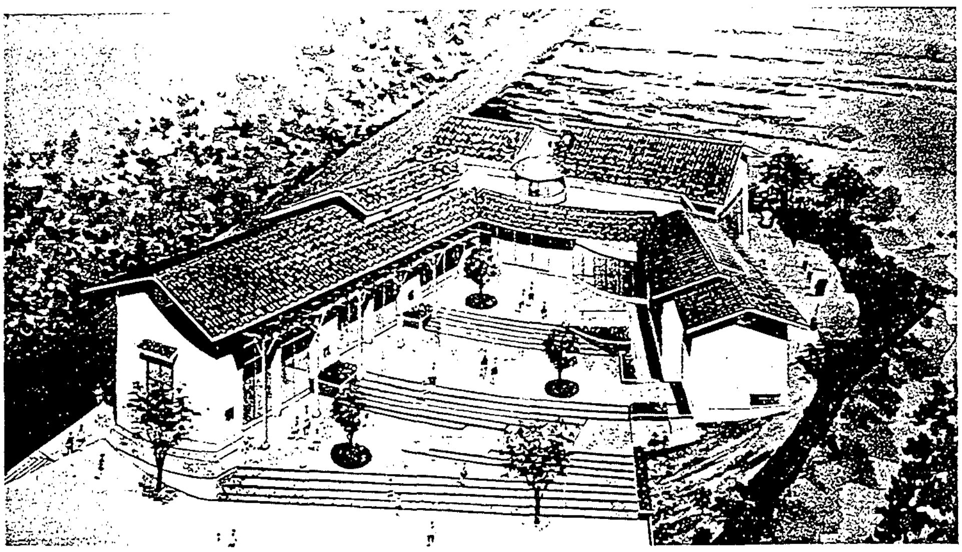


Fig.3 Model-construction „Ogo district welfare center“

PLANNING AND FIELD MEASUREMENTS OF HEATING AND COOLING SYSTEM UTILIZING NATURAL ENERGY FOR K PLAZA BUILDING

Susumu Horikawa
Osaka Environmental, Mechanical & Electrical Engineering Office

1. INTRODUCTION

K Plaza Building was constructed as a core facility of Kansai Science City (KSC), which extends over three Kansai prefectures, i.e., Kyoto, Osaka and Nara. The city is planned to serve as a new foothold in the forthcoming century for development of culture, science and technology. Keeping harmony with the natural surroundings is the basic concept of this city planning. To abide by this basic planning philosophy, it was essential that K Plaza be planned to form a building that would utilize natural energy effectively while being harmonious with its surroundings. This present paper briefly describes how the surrounding climatic conditions were predicted and what sorts of systems were planned to utilize natural energy effectively, and also reports some measured results related to the aforesaid planning considerations.

2. PREDICTION OF SURROUNDING CLIMATIC CONDITIONS

Nowadays, cities are turning out to be "heat island phenomenon" which makes it difficult for us to receive what the nature would otherwise offer to us. If natural energy is to be utilized effectively, the surrounding climatic conditions become the factors that claim the primary consideration. Since all districts of KSC are located in the sites which are richly surrounded by greenery, it is expected that climatic conditions much more favorable than those in densely built-up city areas can probably be maintained. However, the climatic conditions surrounding any building to be constructed in KSC may change depending on the pattern of land use in the block of KSC in which the specific building is to be constructed. Also, in case of the city like KSC, which is currently in the process of development, mere prediction of the climatic conditions surrounding the proposed building at the time of its completion will not serve the purpose satisfactorily. Thus, it was decided that for the planning of K Plaza Building, the surrounding climatic conditions at the time of the completion of all the KSC projects be predicted by using the formula as proposed by Moriyama et al. This formula correlated the outdoor air temperature with the land covering vegetative conditions as obtained from the remote sensing data.

As the flow chart in Fig. 2 indicates, this method developed by Moriyama et al is intended for evaluation of the outdoor air temperature environment by the use of a formula which correlates the temperatures measured at 16 local weather observation stations during 10 years from 1980 to 1989 with the Normalized Vegetation Index (NVI) as obtained at locations around these stations. NVI obtained from the remote sensing data is regarded as excellent indices of the greenery coverage ratio which influence greatly the air temperatures. The formula by which to obtain NVI and the one by which to correlate the NVI with air temperature are shown in Eq. 1 and Eq. 2 respectively.

At the next step, NVI distribution upon completion of the development had to be prepared. To collect necessary date for this, the land use plans of the buildings constructed and those to be constructed in the KSC's block in which K Plaza is located were investigated. These investigations led to the finding that each building was planned to have a sufficient green area around it with an average green coverage ratio of 40 %. Since the remote sensing data that was available was photographed in 1990 when this block was still at the stage of site preparation, the NVI data was converted in such a way that the green coverage ratio in each building site would become 40 %. Shown in Fig. 3 is a map indicating NVI distribution upon the completion of the block development as obtained by the data conversion.

Fig. 4 shows the predicted air temperature distribution as prepared on the basis of the data thus obtained and by the use of the correlation formula indicated in Eq. 2. It is known by comparison that the predicted air temperature distribution in this KSC's block in August is maintained 1 ... 1.5 °C lower than that in Osaka's urban area.

Effective utilization of natural energy depends not only on the lowest air temperature in August but also on many other factors such as the sunshine and wind. However, a means to keep houses cool in summer, which is considered most important for Japanese houses, is more greatly affected by the lowest summer temperature. For this reason, the utilization of natural energy is considered effective in KSC. Fig. 6 shows the temperature distribution for an assumed case where the same district is wholly paved with asphalt. In such a case, the air temperature rise of about 0.5 °C is seen compared with the case where enough greenery is provided. This difference, small as it is, is believed to be significant because the effect of the natural energy utilization itself cannot be expected to be very great. This also indicates that the prediction of the surrounding climatic condition in advance is a matter of importance.

3. OUTLINE OF NATURAL ENERGY UTILIZATION SYSTEM

Fig. 7 and Fig. 8 show a part of the system used for the planning of K Plaza Building.

- Heating/Cooling Tube

In the atrium-style lobby, outside air is taken through subterranean tube (duct). In summer the outside air is cooled by the lower-temperature underground, and in winter it is warmed by the higher-temperature underground.

- Double Roof

The roof of the main conference hall has a double structure that can be used as an air duct. In winter, cold air from outside can be heated by sunshine. In summer, the roof can be cooled by surplus air introduced to double roof from air conditioning system. In order to minimize the initial cost increase due to the use of natural energy utilization system, the planning aimed at effective use of architectural space formed by double layer sheet metal roof over the main hall and pits for the basic utility systems.

4. MEASURED RESULTS OF THE SYSTEM

The measurements were conducted in the summer of 1993 (Sept. 1 ... 7) and in the winter of 1994 (Jan. 30 ... Feb. 4).

4.1 Heating/Cooling Tube

The measurement results as obtained in winter and summer are indicated in Figs. 9 and 10 respectively and also in Table 2. It, however, should be noted that there was air leakage from the room side into the pits during the summertime measurements. Increased effects obtained in winter by inclusion of the pit portion are considered to be attributable to the large contact area with soil. The maximum heating capacity and the maximum cooling capacity of the tube portion were found to be 7.47 kW and 7.0 kW respectively, and the maximum heating capacity including the pit portion was 27 kW. It was also found that the capacity was more stabilized in winter.

4.2 Preheating Outside Air through Double Roof

Fig. 11 shows the measured results. On the both days on which the measur ements were taken, the outdoor temperature was low while there was enough solar radiation; so, the temperature of air taken through double roof was raised 4.4 °C higher on average and 6.1 °C higher at maximum than the outdoor temperature. The roof surface temperature was also raised to 32.7 °C. It was worried that supplying outdoor air into the space in the double roof might result in the increased heat out flow from the interiors because the inner surfaces of the double roof would be cooled off by the outside air introduced into the roof space; however, the hall was of such type that cooling load was generated within the ceiling space even in winter because of the heat strata formed by the high ceiling, no heat outflow problems were thought to be created in this specific case.

4.3 Heat Extraction by Double Roof

Fig. 12 shows the measurement results. The figure indicates that there were an average temperature rise of 4.8 °C and a maximum temperature rise of 8.2 °C at the roof outlet compared with the temperatures at the roof inlet. This means that the heat equal to the difference between the aforesaid two temperatures was extracted from the roof space. The maximum heat extraction capacity during the measurement period was 46 kW.

5. CONCLUSIVE REMARKS

The following facts were found through a series of planning and measurement experiences gained during the implementation of K Plaza Building.

(1) A technique using remote sensing data is effecting for predicting the climatic conditions at the time of the completion of the district development.

(2) Climatic conditions surrounding a building are affected by the ground covering. In planning a natural energy utilization system, the prediction of the surrounding climatic conditions is very important.

(3) As for the heating/cooling tube, the heating capacity is more stabilized. Also, it is believed that such capacity is greatly affected by the contact area with the soil. The maximum heating and cooling capacity at the tube portion was about 7.0 kW and its maximum heating capacity including the pit portion was 27 kW.

(4) The measurement results indicate that the double roof has the maximum capacities of 34 kW and 46 kW in respect of outside air preheating and heat extraction respectively.

The studies reported in this paper were intended only to determine, based on the prediction of climatic conditions surrounding a building, whether or not it was possible to utilize natural energy to advantage; however, the author has a further plan to develop some simulation models which will make it possible to evaluate the effects of natural energy utilization on a quantitative basis and also to make studies which are conductive to development of some means by which to improve the sensibility of the remote sensing technique.

The author wishes to conclude this paper with his grateful acknowledgment of help and advice that he received from Dr. Moriyama of Kobe University, Mr. Suzuki, researcher at the same university and Mr. Miyazaki of Himeji Institute of Technology in the course of the research studies.

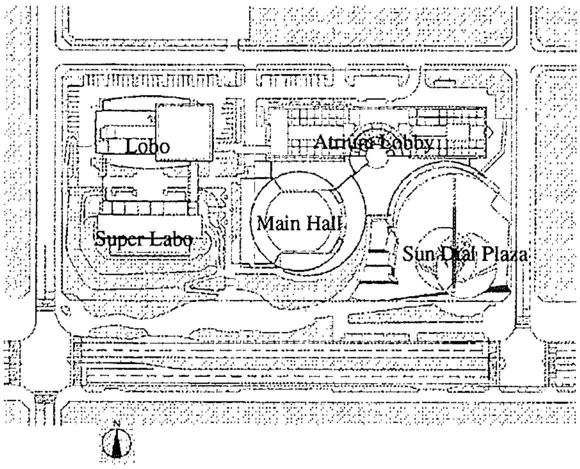


Fig.1 Block Plan

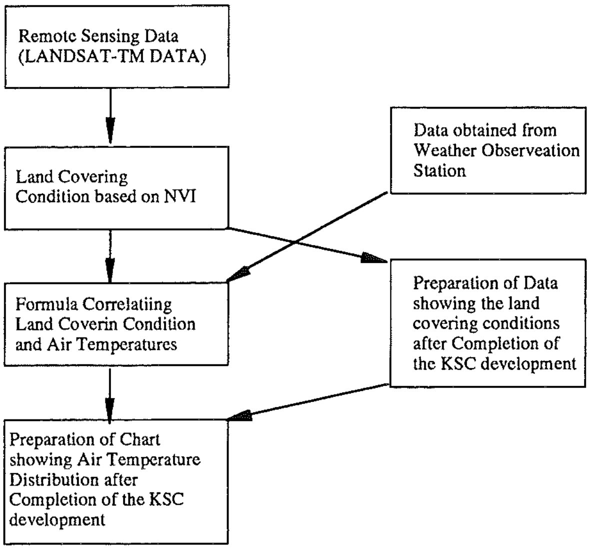


Fig.2 Surrounding Climate Prediction Chart

Table 1 Outline of Building

Location	Soraku-gun, Kyoto Pref. (Kansai Science City)
Intended Use	Multipurpose Hall, Hotel and Rental Labos
Scope of Bldg.	Total floor area: 40,576 sq.m 13 aboveground floors with a basement

$NVI = (Band\ 4 - Band\ 2) / (Band\ 4 + Band\ 2) + 2$ ··· Eq. (1)

where, Band is the wavelength band of Landsat TM Data in which,

Band 2: Near infrared region (0.76μm ~ 0.90μm)

Band 4: Visible region (0.52μm ~ 0.60μm)

$t = -4.97174 \times (NVI) + 25.8851$ ··· Eq. (2)

Where, in the formula for obtaining the lowest temperature in August.

t: Air temperature (°C)

NVI:Normalized Vegetation Index

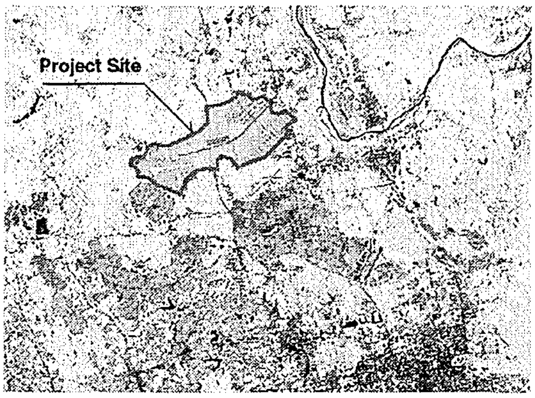


Fig 3 Post-Development NVI Distribution

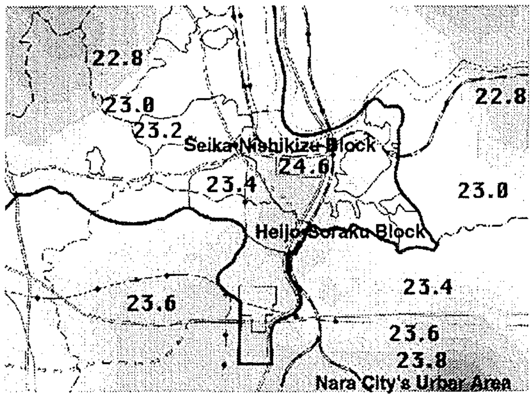


Fig 4 Predicted Post-Develoement Air Temperature Distribution

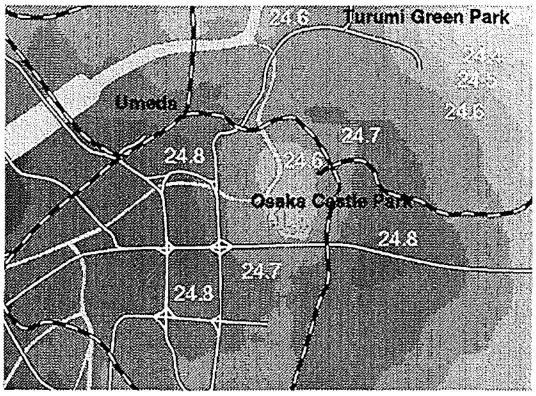


Fig 5 Predicted Air Temperature Distribution in Osaka's Urban Area

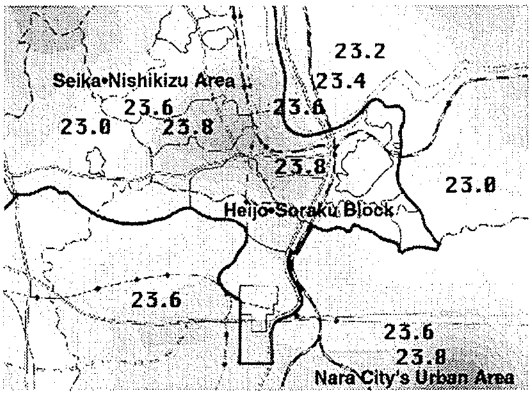
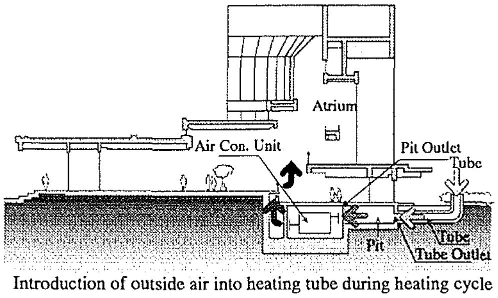
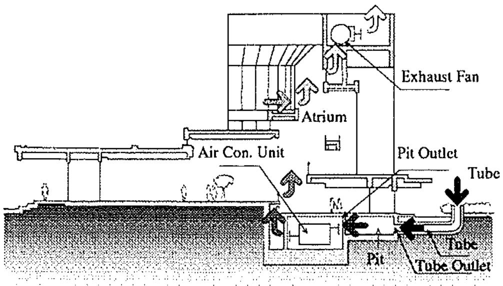


Fig 6 Predicted Air Temperature Distribution in the Area Shown in Fig 4 when the area is fully covered by asphaltic pavement



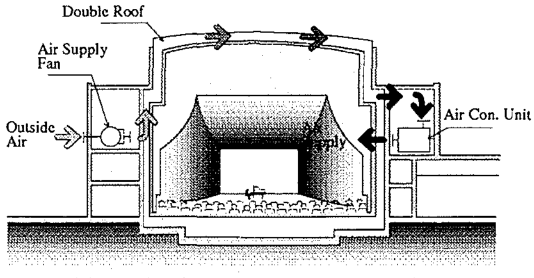
Introduction of outside air into heating tube during heating cycle



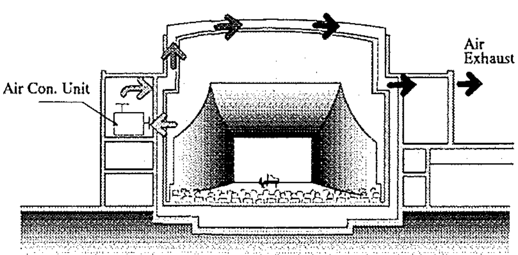
Introduction of outside air into cooling tube and heat exhaust from the top during cooling cycle

Heat transfer area:	tube portion 150 sq.m pit portion 900 sq.m
Air Flow Rate:	7,800 CMH

Fig. 7 Concept Drawing of Heating/Cooling Tube



Utilizing outside air after heating it with solar radiation



Heat shielding by surplus air from air conditioning system

Heat collecting area	699 cu.m
Air Flow Rate	16,600 CMH

Fig. 8 Concept Drawing of Double Roof System overthe Main Hall

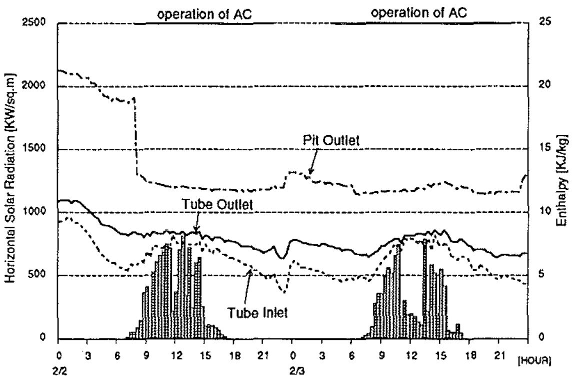


Fig. 9 Measured Results of Heating Tube Performance

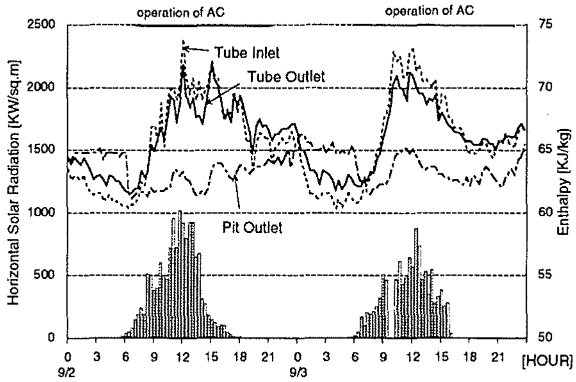


Fig.10 Measured Results of Cooling Tube Performance

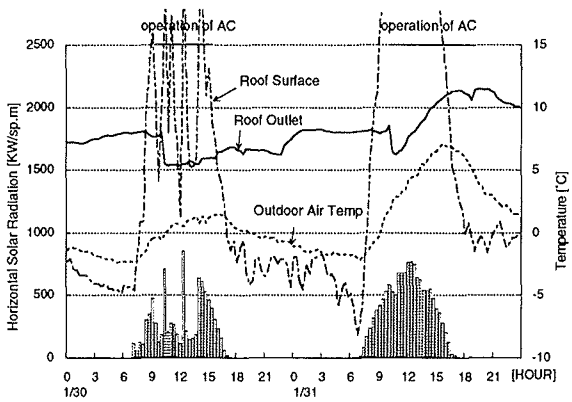


Fig. 11 Measured Results of Reheating of the Hall's Outside Air

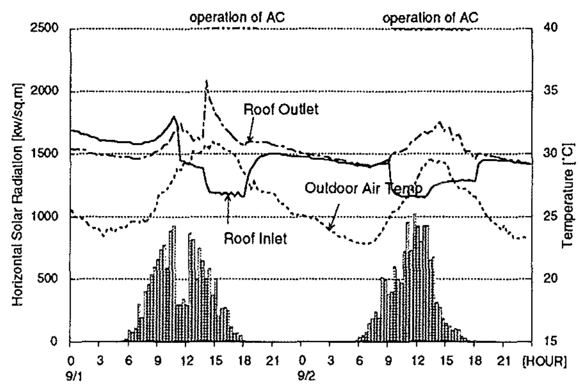


Fig. 12 Measured Results of Heat Removal from the Hall

Table 2 Measured Results of Heating/Cooling Tube Performance

	2/2		2/3		9/2		9/3	
	ABE	MAX	ABE	MAX	ABE	MAX	ABE	MAX
Difference Enthalpy (KJ/kg) at Outlets/Inlets of Tube Porrtion	1.50	2.82	6.40	13.45	0.55	2.68	4.17	10.67
Difference Enthalpy (KJ/kg) at Outlets/Inlets of Pit Porrtion	1.23	2.17	5.59	7.36	0.71	2.69	3.96	8.90

SURVEY OF OUTDOOR AIR TEMPERATURE DISTRIBUTION ON THE SITE OF EXPOSITION

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ABSTRACT

Air temperature distribution on the site of exposition was observed. To investigate the influence of land use on local temperature, two types of regression analysis was examined. One is a multiple regression analysis between the air temperature and land use ratio, the other is a regression analysis between air temperature and sensible heat discharge. From these results, it is clear that relationship between the local air temperature and land use within the circle about 100m in radius is close in nighttime.

INTRODUCTION

The purpose of this study is to investigate the effects of materials for ground surface and artificial waste heat on local scale distribution of air temperature. In the case of applying this phenomena to outdoor space design, the information how large area of surrounding land use condition affect the air temperature at a certain point is important. The authors call such size "control scale of thermal environment".

One of the authors (Mizuno et al., 1990) has paid an attention to the relationship between a land use and local temperature in a small area which is about 1km around, and has carried out some field measurements. In this study, field survey of thermal environment on the site of "International Garden and Greenery Exposition", which was held from April 1 to September 30 at Turumi Green Park in Osaka Japan, was carried out.

The reasons why we selected this site as the object of the study are as follows.

1) This site consisted of several areas, and these areas included "Mountain Area", where there were plenty of trees and gardens, and "City Area", where there were pavilions and wide ground paved with artificial material. Then, we had expected that it would be possible to observe air temperature distribution, which was caused by the different land use in two areas.
2) Generally, in a site of an exposition, visitors tend to stay in the outdoor space for a long time. Then, the adjustment of thermal environment in outdoor space of exposition site is an important point, especially in temperate regions such as Japan. In the fact, due to the lack of the adjustment, the number of the visitors of this exposition decreased suddenly during the hottest period in summer. Therefore, the results of this study will be useful for a future exposition site planning.
3) In the site, the amounts of electric power, gas and cold heat consumption were measured. These data will enable to estimate the amount of waste heat discharge.

In this survey, two types of air temperature observation were performed.
1) Fixed point observation : At seven points in the site, outside air temperature was continuously measured for about a week each in June, August and

September.
2) Migratory observation : During each period of fixed point observation, migratory observation on foot was carried out 10 times.
Figure 1 shows the site of survey and distribution of measurement points. The number of measurement point is 60. The following parts, the results of the migratory observation are focused.

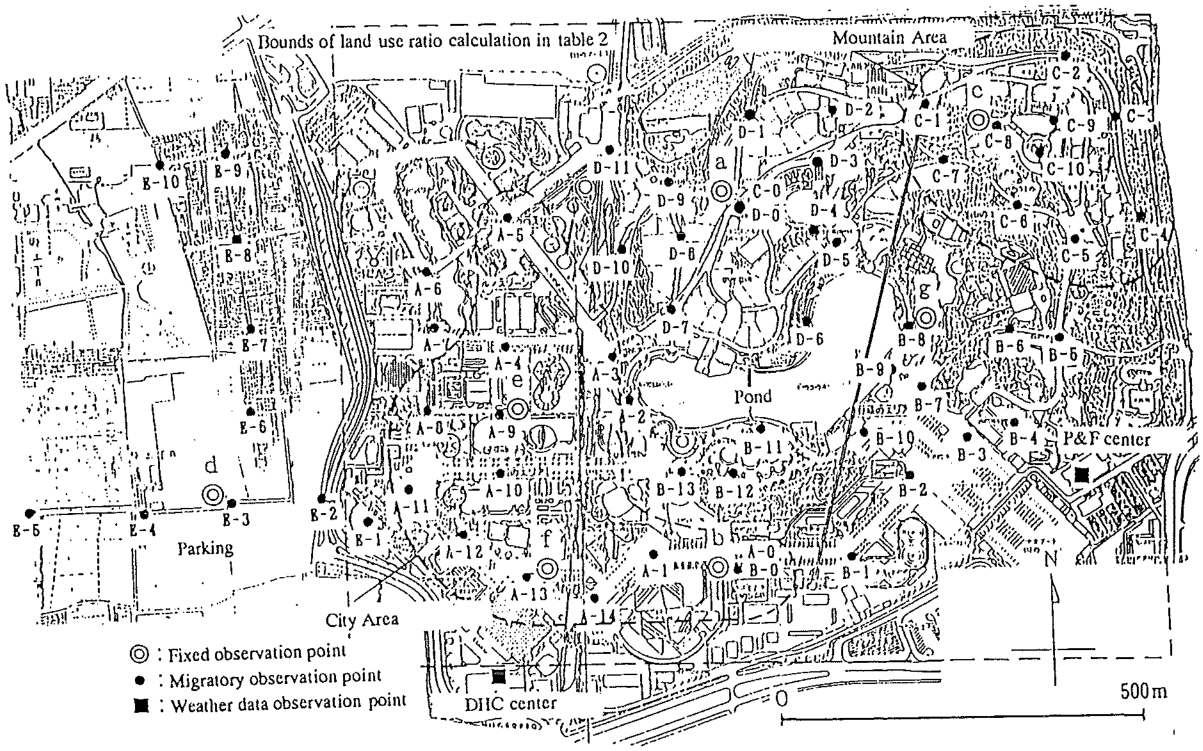

Figure 1. Site of observation and distribution of measurement points.

SURVEY METHOD

Air temperature at migratory observation is measured by electronic digital thermometer. The sensor of the thermometer is set in a tube, which is made of vinyl chloride, and air is sucked into the tube by a fan. To diminish any measurement error caused by radiation, the tube is covered with aluminum. Five instruments were used in this survey, then instrumental errors are calibrated before the survey. Each measurement takes about 30 minutes, then measured temperatures were corrected by time change of fixed point observation results. Table 1 shows the summary of migratory observation results.

PRODUCTION OF LAND USE MAP

To examine the relationship between air temperature and surrounding land use, land use map at exposition site was inputted to personal computer. The land use ratio in the circle around the air temperature measuring point was calculated by counting dots of screen. One dot of the screen is equivalent to 1.25m × 1.25m square. Land use ratio in the area bounded by broken line in figure 1 is shown in table 2.

Table 1. Summary of migratory observation results. Unit :[℃]

Run No.	Date&time		Maximum (Point)	Minimum (Point)	Average	Standard Deviation
RUN-1	Jun.4	14:00	26.6(B-0)	24.1(C-10)	25.3	0.484
RUN-2		19:00	19.9(A-4)	18.8(D-9)	19.4	0.264
RUN-3	Jun.6	19:00	27.2(E-10)	24.8(D-3)	26.3	0.448
RUN-4	Jul.31	11:00	33.0(E-9)	29.6(C-6)	31.2	0.669
RUN-5		13:15	34.8(E-3)	31.6(C-2)	32.9	0.740
RUN-6		17:40	33.8(E-3)	31.0(E-1)	32.4	0.558
RUN-7		20:00	30.1(A-5)	27.6(D-9)	29.2	0.477
RUN-8	Aug.3	13:00	37.0(B-1)	33.8(C-4)	35.4	0.656
RUN-9		17:00	38.5(E-3)	35.5(B-2)	37.1	0.604
RUN-10	Sep.27	15:00	28.4(A-5)	26.6(D-4)	27.5	0.394

Table 2. Land use ratio in the area bounded by broken line in figure 1.

Classification of Land Uses	Ratio(%)	Classification for Multi-regression analysis
Impervious Asphalt (Black)	13.3	(Asphalt)
Pervious Asphalt (Black)	21.9	(Asphalt)
Pervious Asphalt (Painted in light color)	3.8	(Asphalt)
Building	16.1	(Building)
Concrete	3.8	
Rubber	0.2	
Wooden floor	2.0	
Grass	16.1	(Grass)
Woods	10.8	(Woods)
Water surface	7.0	(Water surface)
Bare ground	5.1	

MULTIPLE REGRESSION ANALYSIS BETWEEN THE AIR TEMPERATURE AND LAND USE

From migratory observation results and land use map mentioned above, multiple-regression analysis was examined. The model equation is expressed by

$$\theta = a_0 + \sum_{i=1}^{N} a_i X_i \qquad (1)$$

where θ is a temperature, the a_is are the partial-correlation coefficients and the X_is are the land use ratios of the land use number i. The land use categories selected in this analysis are asphalt, building, grass, woods and water surface as shown in table 2. Land use ratios are calculated within a circle around each measurement point defined by a radius which is called the 'evaluated radius'. Evaluated radius was varied from 10m to 200m. Figure 2 shows the relation between the size of evaluate radius and multiple correlation coefficient. Generally, the multiple correlation coefficients in the nighttime are comparatively higher than that in the daytime. They increase with the evaluated radius where it is smaller than 50m, and they are nearly constant where it is larger than 50m.

About four measurements which multiple correlation coefficients are relatively high, multiple regression analysis between the air temperature and land use in a half-circle on the windward side were also investigated. Figure 3 shows comparison of the multiple correlation coefficients which land use is calculated within a circle with that which it is calculated within a half-circle. The multiple correlation coefficient is almost higher in the case of the half-circle on the windward side than in the case of the circle where evaluated radius is small.

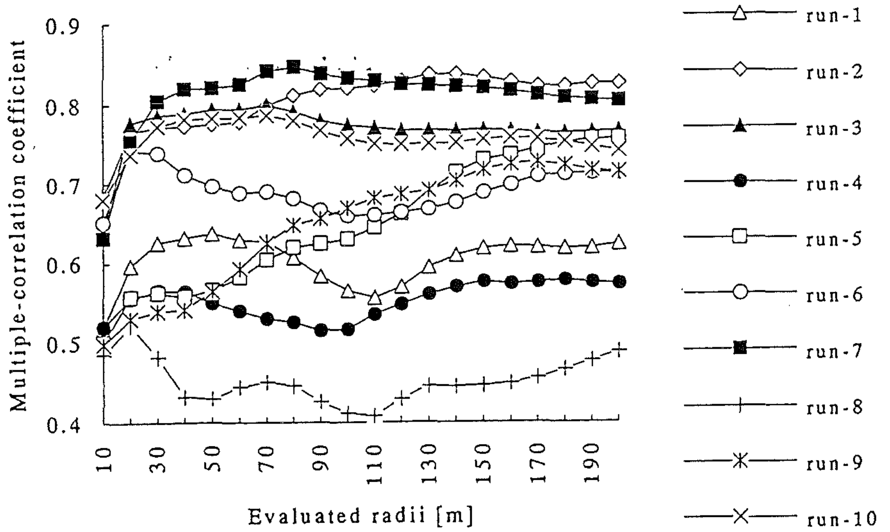

Figure 2. Relation between the evaluate radius and multiple correlation coefficient.

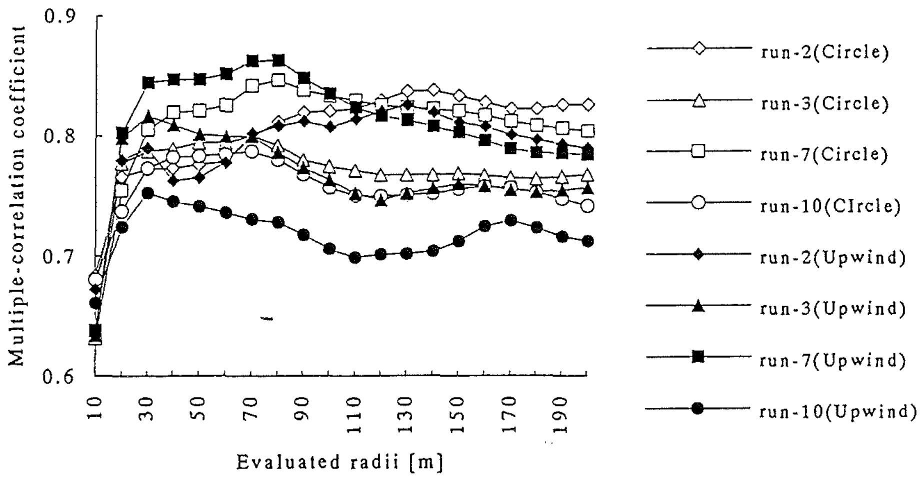

Figure 3. Effect of the wind direction.

The standard partial regression coefficients a^*_is in the standardized form of eq. (1)

$$\theta^* = \sum_{i=1}^{N} a^*_i X^*_i \tag{2}$$

are shown in table 3 on conditions that the evaluated radius are 20m and

70m. The strength of the asphalt pavement on the rise of air temperature is the highest among the five land uses. On the other side, the strength of the woods on the reduce of air temperature is the highest.

Table 3. Standard partial regression coefficients and multiple-correlation coefficients at R=20m and 70m

Evaluated Radii		RUN-1	RUN-2	RUN-3	RUN-4	RUN-5	RUN-6	RUN-7	RUN-8	RUN-9	RUN-10
20m	Building	0.335	0.118	0.445	0.364	0.324	0.309	0.337	0.170	0.181	0.295
	Asphalt	0.600	0.480	0.563	0.308	0.509	0.451	0.492	-0.088	0.215	0.587
	Grass	0.161	-0.194	-0.101	-0.156	0.059	-0.101	-0.106	-0.190	-0.056	0.006
	Woods	-0.606	-0.234	-0.075	0.025	-0.043	-0.249	-0.200	-0.395	-0.267	-0.180
	Water s.	0.074	0.218	0.312	-0.031	0.054	0.115	0.168	-0.151	-0.114	0.075
	M.C.Coef.	0.597	0.766	0.777	0.555	0.557	0.743	0.754	0.522	0.530	0.737
70m	Building	0.512	0.259	0.579	0.281	0.385	0.290	0.457	-0.200	0.383	0.495
	Asphalt	0.779	0.082	0.576	0.325	0.740	0.601	0.445	-0.285	0.747	0.604
	Grass	0.524	-0.323	0.131	0.096	0.350	0.206	-0.055	-0.176	0.578	0.161
	Woods	-0.018	-0.303	-0.044	-0.075	0.017	-0.184	-0.136	-0.639	-0.111	-0.097
	Water s.	0.167	0.121	0.225	-0.155	0.119	0.144	0.141	-0.205	-0.003	0.166
	M.C.Coef.	0.627	0.799	0.800	0.530	0.604	0.690	0.842	0.451	0.625	0.787

REGRESSION ANALYSIS BETWEEN THE AIR TEMPERATURE AND SENSIBLE HEAT DISCHARGE

In the previous section, we chose land use ratio as explanation variables of regression analysis. However, sensible heat discharge from earth surface affects the air temperature directly. Then, regression analysis between sensible heat discharge and air temperature is examined. The sensible heat discharge from earth surface was estimated from heat balance equation (Ojima and Moriyama, 1978) and weather data. The artificial sensible waste heat discharge was estimated from the amount of electric power, gas and cold heat consumption and number of visitor, and it is assumed that it is discharged from building only.

Figure 4 shows the estimated total sensible heat discharge from the area bounded by broken line in figure 1 at the hour of RUN-5 and RUN-7. In the daytime, sensible heat flow from asphalt pavement is dominant. On the other side, artificial sensible heat discharge in the nighttime becomes 51% of total sensible heat discharge.

Figure 5 shows the result of regression analysis between air temperature and sensible heat discharge from earth surface within a circle around each measurement point defined by the 'evaluated radius'. Air temperature measured points used in this analysis were restricted in the area bounded by broken line in figure 1. In the nighttime, correlation coefficient is larger than that in the daytime and relationship between the evaluated radius and correlation coefficient is almost the same as multiple regression analysis.

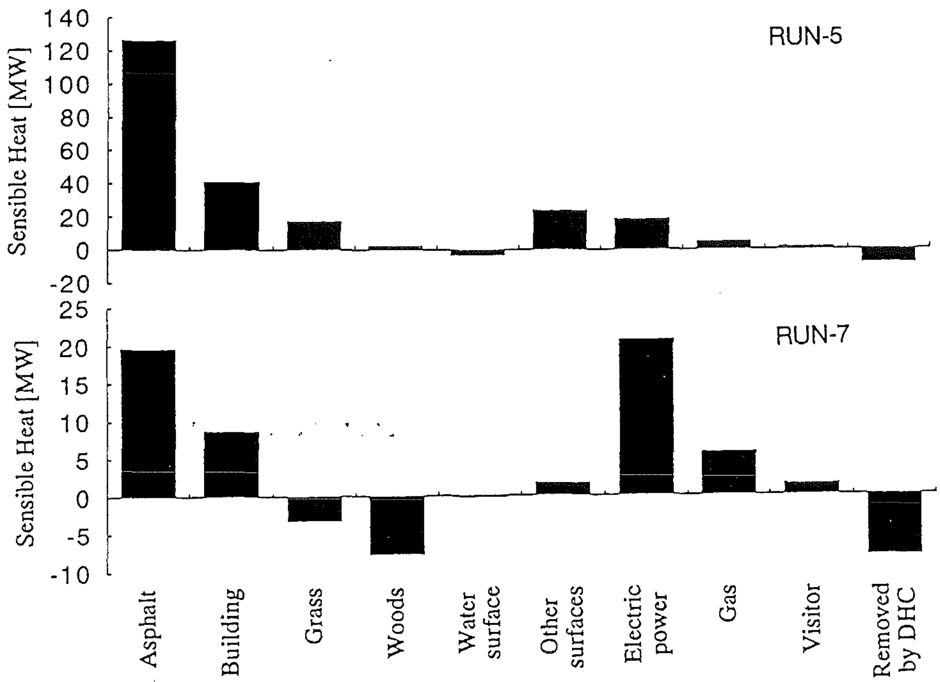

Figure 4. Estimated total sensible heat discharge from the area bounded by broken line in figure 1.

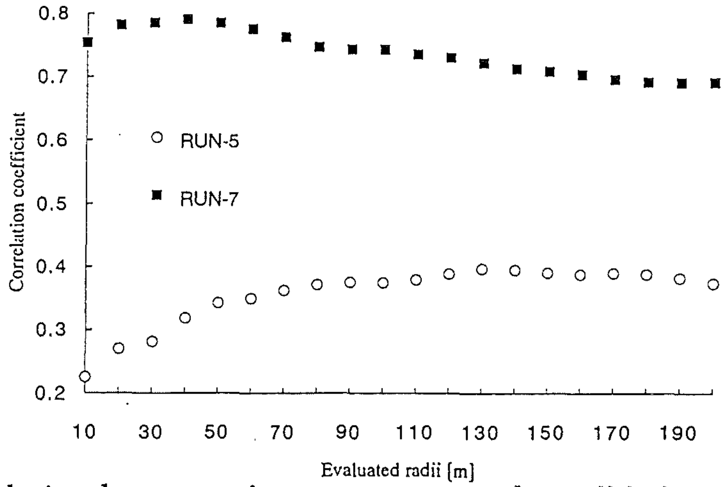

Figure 5. Relation between air temperature and sensible heat discharge.

CONCLUSIONS

From the result of regression analysis, it is clear that the relationship between an air temperature and surrounding area in about 100m radius is close in the nighttime. Then it is possible to decrease air temperature by change of land use and by decrease of artificial heat discharge in such a small area.

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VERTICAL TEMPERATURE AND HUMIDITY PROFILES IN OSAKA CITY AND ITS EFFECT ON AIR-CONDITIONING LOAD

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ABSTRACT

Temperature and humidity in upper atmosphere are different from those of the ground level. For the design of thermal performance of buildings and air-conditioning systems, weather data obtained at a meteorological station are commonly used not depending on the building height. However, the climatological difference may result in significant mistakes in the design of highrise buildings. Observations of temperature and humidity in urban areas of upper atmosphere below several hundreds meters high, where most buildings exist, has not been reported abundantly. In the present study the results of temperature and humidity observations at different height and locations in Osaka city, the second largest city in Japan with population of 2.5 million, are reported for summer and winter season. The way to express the results is based on the weather model which was proposed by one of the authors. The structure of the weather model has mathematical expressions, for instance, the random variations are modeled by an ARMA time series formula. Finally the difference in air-conditioning loads estimated for the upper and lower climate is discussed

1. INTRODUCTION

In Japanese large cities highrise buildings have been built since the late 1960's. Although the number of new highrise constructions and projects decreases due to the present economic recession, the demand of highrise buildings is still high. One reason is that Japanese land is small and especially in urban areas shortage of land or open space is a serious issue. Providing highrise buildings, which can make urban areas more spacious, is a solution for this problem. Since the average building height in Tokyo is estimated less than 2 stories, increasing the number of story in buildings will be a remedy to improve the urban environment, above all, the thermal environment.

Temperature and humidity in upper atmosphere are different from those of the ground level. For the design of thermal performance of buildings and air-conditioning systems, weather data obtained at a meteorological station are commonly used not depending on the building height. However, the climatological difference may result in significant mistakes in the design of highrise buildings.

The municipal government of Tokyo has already been promoting or enforcing that every type of highrise buildings should include residential spaces. The purpose of this policy is to avoid making Tokyo a monotonous city by keeping residential activities inside urban areas. Usually the residential floors are located in the upper part of the highrise buildings, consequently, the upper weather information is necessary in this context also.

2. OBSERVATIONS

Observations of temperature and humidity in urban areas of upper atmosphere below several hundreds meters high, in which layer most buildings exist, has not been reported abundantly. Especially long term observations are limited. The reason is that the common way for observations is the use of balloon or kytoon, although, for loan term observations a fixed tower structure is required. Our observations were carried out by installing measuring devices in high-rise buildings in Osaka city, which is 500 km west of Tokyo and the second largest city in Japan with a population of 2.5 million.

The locations of buildings are shown in Fig. 1 with population density. Most buildings are located in densely populated urbanized areas. For comparison ground level observatory in suburbs:

Suminodo and water front observatory close to Osaka bay: Nanko were provided. Weather data recorded at the Osaka meteorological station were used for our study. The observation periods were 28 days of summer from July 22 to August 18, 1992 and 15 days of winter from January 26 to February 9, 1993.

Temperature and humidity sensors were placed at the northeast and the southwest corners of each building in order to catch free stream air and avoid the effect by the building itself. The time interval for observations was 5 minutes and the lower temperature among the two directions was chosen as the true values not affected by own building. Furthermore the minimum temperature that finally represents the hourly data was chosen among 12 readings for every one hour. By doing this very accurate data were obtained. The accurateness of this method was checked by laboratory test and the standard deviation of the errors was found to be 0.2 to 0.3 K. In terms of humidity values associated with the temperatures chosen by the above procedures were used.

3. WEATHER MODEL

Comparing the observed data the characteristic of temperatures and humidity at different elevations can be understood, although, for the evaluation of air-conditioning loads at an arbitrary height weather data at any height and any term of a year must be provided. For this purpose an weather data model based on mathematical expression, which was proposed by one of the authors [5) is used.

The weather model is composed of deterministic and stochastic components and they are modeled by Fourier series and an AR (auto-regressive) or an ARMA (auto-regressive and moving average) time series model respectively. The deterministic component are further decomposed into three sub-components: annual average, annual periodicity and diurnal periodicity. The comparison of the observed data at different elevations are investigated based on this model. The structure of the model is shown briefly in Fig. 2.

4. RESULTS OF OBSERVATIONS

4-1 Temperature

a) Average values (Fig.3)

The average temperatures at different height decreases linearly with altitude. Since influential water vapor condensation will not mostly take place below the highest observation point (180 m), the rate of decrease should be approximated as dry adiabatic lapse rate; 0.0098 K/m. The values for the summer and the winter period is 0.0106 K/m and 0.0089 K/m respectively and these are very similar to the dry adiabatic lapse rate.

The difference between locations inside urban areas were not unexpectedly significant, namely, temperatures are homogeneous. In summer the ground level temperatures in water front areas were lower than those of inland urban areas but the upper temperatures were almost the same. In winter the reverse occurred. This is not physically proven however, the dominant wind direction in summer is southwest and northeast in winter should have strong relation.

The values of the meteorological station were higher than our observations for both season. The reason will be supposedly due to the difference in measuring instruments and geographical site conditions.

b) Diurnal periodicity (Fig.4)

The amplitudes of diurnal periodicity did not depend on height and the average value is 0.8 times of the value of the meteorological station for both summer and winter. This results are different from the reported values observed on a open land [4). The reason may be that the ground level spots of our observations were surrounded by buildings without spacious open spaces. In fact the values of the suburban spot: Suminodo, where measuring instrument was located in a school site surrounded by open spaces, showed the same values as those of the meteorological station.

c) Stochastic components (No figure)

Stochastic components were evaluated by the standard deviation of the random variations. The ratio of the values to those of the meteorological station was 0.9 for summer and 1.0 for winter in average. The difference between altitudes and locations were very little and not greater than 0.2 K that can be negligible for the purpose of building designing.

4-2 Humidity

a) Average values (Fig.5)

The values in urban areas are very similar to those of the meteorological station in both seasons, however, the values of the ground level in the water front and suburbs differed significantly with those of the meteorological station in summer. This is due to the sea and the surface condition of the land. It was observed that urban areas are dry in summer but not in winter. No difference was detected in values in upper atmosphere.

b) Diurnal periodicity (No figure)

Since no significant diurnal periodicity is recognized in humidity in general, investigation was not been made.

c) Stochastic components (No figure)

The ratios of standard deviation were investigated as the same way of temperature and no significant difference was observed.

5. ESTIMATION OF UPPER WEATHER DATA

The results of observation cannot be used as the raw data because they are the weather data of a specific heights, locations and periods. We need the weather data of arbitraly height, location and for whole year. For this requirement authors propose the following weather model based on the above investigations.

$$\begin{aligned} \theta &= (\bar{\theta}_o - \Delta\bar{\theta}) + \tilde{r}_T\tilde{\theta}_o + r_{T,s}\theta_{o,s} \\ x &= (\bar{x}_o - \Delta\bar{x}) + r_{x,s}x_{o,s} \end{aligned} \qquad (1)$$

θ : estimated temperature [K]

$\bar{\theta}_o$: average temperature for the observation period [K]

$\Delta\bar{\theta}$: compensation for height [K]

$\tilde{\theta}_o$: diurnal periodicity [K]

$\theta_{o,s}$: stochastic component [K]

x : estimated humidity [g/kg']

$\bar{x}_o$: average humidity for the observation period [g/kg']

$\Delta\bar{x}$: compensation for height [g/kg']

$x_{o,s}$: stochastic component [g/kg']

$\tilde{r}_T$: compensation ratio for diurnal temperature periodicity [-]

$r_{T,s}$: compensation ratio for stochastic temperature component [-]

$r_{x,s}$: compensation ratio for stochastic humidity component [-]

Values for compensation are obtained by the following formulas.

$$\begin{aligned} \Delta\bar{\theta} &= -0.0098h - 0.1246 \\ \tilde{r}_T &= -0.00189h + 1.00681 \\ r_{T,s} &= -0.00034h + 1.0006 \\ \Delta\bar{x} &= -0.00083h + 0.10533 \\ r_{x,s} &= 0.0038h + 0.9987 \end{aligned} \qquad (2)$$

6. EFFECTS TO AIR-CONDITIONING LOADS

The average, diurnal periodicity and random variations with time of the upper air temperatures are different from those of the ground level as investigated above. For comparison, the ratio of estimated air-conditioning loads at a certain height to estimated loads based on the weather data of the meteorological station was obtained. A typical office compartment was used for the comparison, therefore, the results only show one example of height effects. A hypothetical building for the comparison is assumed to be located in the site No. 6 of ORC2000. Solar radiation, and wind velocity and directions also give an influence to the loads. Solar radiation was assumed to be constant with height and wind velocity was adjusted with height according to the logarithmic law.

Three kinds of average loads during the summer and winter periods were estimated; loads calculated by the observed raw data (R), the modeled weather data (M) and the data of the meteorological station (S). The results are shown in Fig. 6. Hereafter the difference is expressed by the increase or decrease rate to the loads estimated by the data of the meteorological station.

In summer the average load at the ground level is 3 % smaller. This is simply due to the lower average temperature at the location, however, the difference is not significant. The loads at 70 m and 150 m high are 9 % and 16 % smaller respectively. If it is assumed that the load decreases linearly with height, the lapse rate is roughly 0.1 %/m. This means 20 % decrease at 200 m high. We cannot ignore the magnitude.

In winter the average load at the ground level is 2 % larger. The loads at 70 m and 150 m high are 12 % and 20 % larger respectively. The increase rate is roughly 0.13 %/m. This means 26 % increase at 200 m high.

The estimated loads based on the modeled data are very close to the real ones. It is unrealistic to observe weather data at the site where a high-rise building construction is planned. Therefore the modeled data is useful in an engineering point of view.

7. CONCLUSIONS

In the present study the results of the observations of upper atmosphere temperature and humidity in Osaka urban areas are reported. Comparing the observed data differences between height and locations are discussed, then the results of air-conditioning loads of a high-rise building are shown with the comparison between different altitudes. The summary of the study as follows.

1) The average temperatures roughly decrease with height according to the physical adiabatic lapse rate 0.0098 K/m.
2) The temperature and humidity variations are investigated based on a mathematical weather model proposed by one of the authors. The difference of weather data can be analyzed systematically by the procedure.
3) Air-conditioning loads of a high-rise building were estimated. It was found that about 20 % decrease in cooling loads and 26 % increase in heating loads will take place for the compartment with 200 m height, therefore, the difference in loads due to height is too large to be ignored.

In the present study no comparison has been made in terms of variations and difference in hourly basis, therefore, more detailed investigation is necessary. These studies will be made as a future work.

Authors would like to acknowledge the building owners and staffs of construction companies who assisted our observations earnestly with support of our study.

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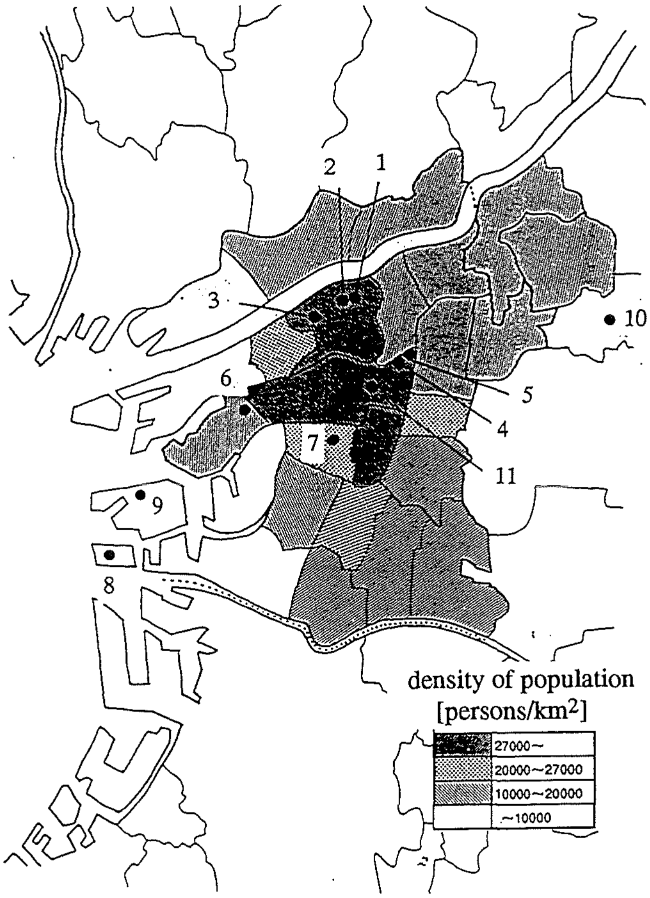
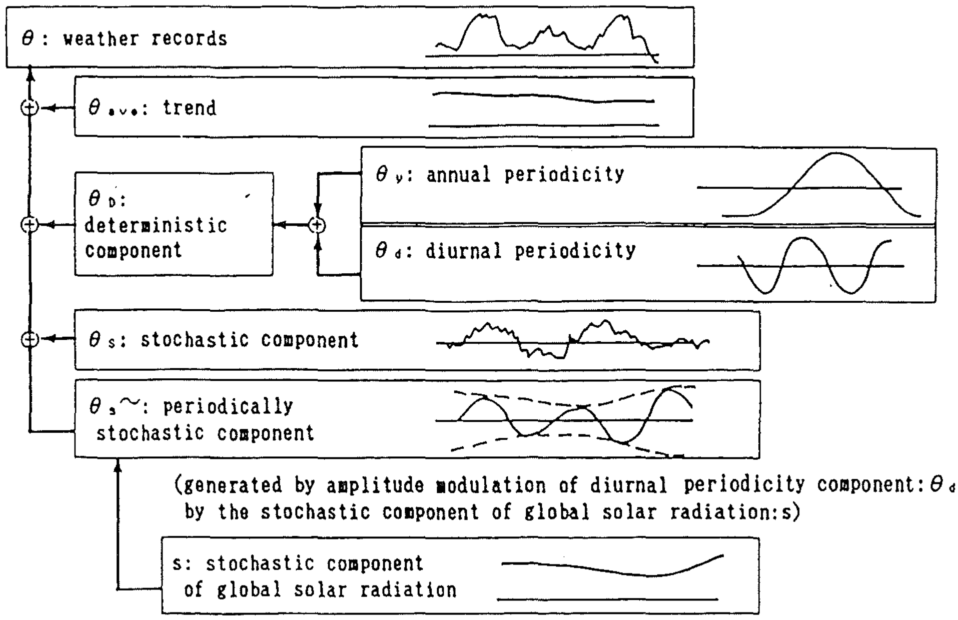


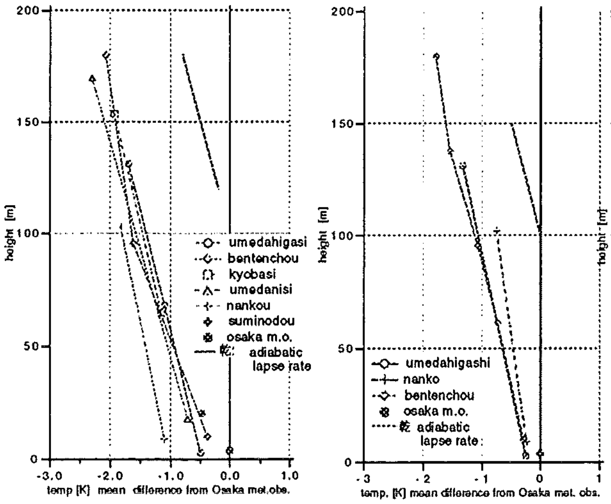
building name	maximum height [m]
1. Umeda Center Building	132.2
2. Mainichi Broad Casting Co.	68.4
3. Umeda Sky Building	170.0
4. Crystal Tower	153.8
5. Yomiuri Television Build.	72.4
6. ORC2000	180.0
7. Nankai South Tower	155.1
8. Kanden Power Plant	180.0
9. Mizuno Crista	126.8
10. Suminodo J.High School	20.1

Fig. 1 Observation point



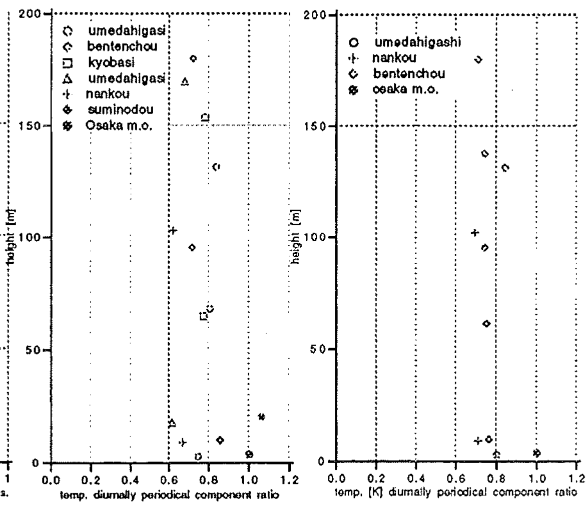
(a) Structure of temperature: θ model.

Fig. 2 Weather data model structure of temperature case



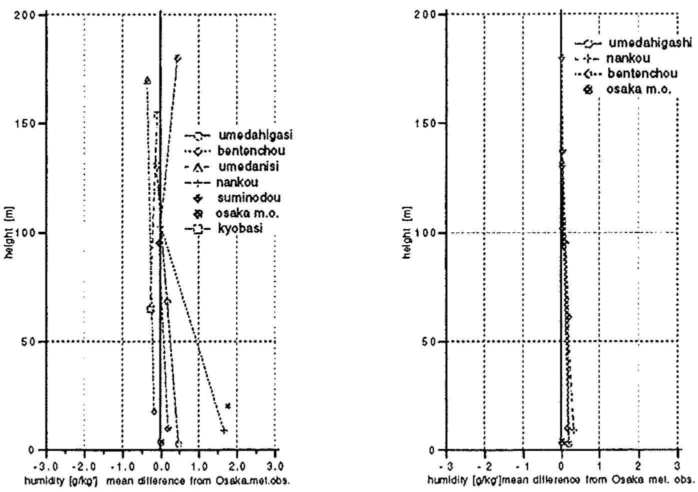
summer winter

Fig. 3 The differnce of average temperature compared to the values of the meteorological station



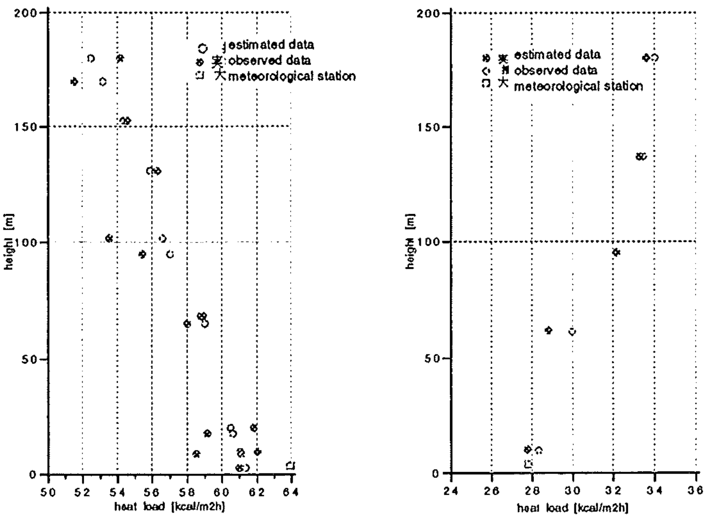
summer winter

Fig. 4 The ratio of diurnal periodicity to the values of the meteorological station



summer winter

Fig. 5 The differnce of average humidity compared to the values of the meteorological station



summer winter

Fig. 6 The differnce in air-conditioning loads with height

HEAT FLUX ABOVE THE ROOF OF A BUILDING BY TURBULENT MEASUREMENTS

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ABSTRACT

The characteristics of heat fluxes in the surface boundary layer are well understood over spatially homogeneous and smooth surfaces (such as grassland and fields). However, they are not always comprehended in urban area, where the surface boundary layer will be considered separately in two parts: the inertial sublayer and the roughness sublayer. In the roughness sublayer, the flow tends to act three-dimensionally, owing to the influence of individual roughness elements. Thus it was difficult to grasp the characteristics of the heat fluxes in this layer by observation, and little research were carried out.

This study aims to examine heat and moisture transfer characteristics outdoors. We measured turbulent heat fluxes by eddy-correlation method at the top of four stories building. The measuring heights were 1.8, 3, and 6 m above the roof level, which was 15.7 m high. The obtained results show that: 1) there are some correlations between turbulent velocities and heat fluxes; 2) during the daytime, vertical differences of turbulent fluxes existed; 3) during the nighttime, turbulent fluxes were small and similar at every height; 4) the Bowen ratio was nearly constant at every height.

INTRODUCTION

When we discuss urban environment from thermal viewpoint, it is more efficient to consider about heat flux than temperature, because the fluctuation of temperature results from the transport of heat. Therefore it becomes more important how to grasp heat fluxes. There are some means toward the measurement of vertical fluxes in the surface layer, for example, eddy-correlation method, profile methods and so on. The eddy-correlation method measures the flux directly by sensing the properties of eddies as they pass through a measurement level on an instantaneous basis. The profile methods infer the flux on the basis of average profiles of atmospheric properties and degree of turbulent activity. The advantage of eddy-correlation method is that it is direct and simple, and fluxes can be calculated at whether height and location that the original time series have been measured. But this method needs expensive fast-response sensors, setting and adjusting the instruments is difficult.

This study aims to examine heat and moisture transfer characteristics by the eddy-correlation method. The detailed explanation about measurement is stated in next chapter.

OBSERVATION SITE AND INSTRUMENTATION

Observations for this study were carried out at the top of four stories building in Kyoto, Japan, as shown figure 1. Imadegawa street where the traffic is congested during the daytime run at the north side of the building. The area surrounding the building is characterized by similar buildings of approximately 15 m high within a radius of about 200 m.

Table 1 shows instruments used in the study. Wind velocity data was obtained by a three-dimensional sonic anemometer (Kaijo, model: DA-600, probe: TR-61C). Roth (1991) indicates that inevitably the bulky array of this sensor arrangement causes distortion of the velocity field of measured, then we followed the correction procedures of Rotach and Calanca (1989), who conducted a wind tunnel calibration on the same sensor. The fluctuations of absolute humidity were measured by an infrared hygrometer (Kaijo, model:AH-300, probe: HGA-100). A fine T-type thermo-couple with 0.076 mm diameter was used to measure temperature fluctuations. We adopted equations shown in Table 2, which is suggested by Satoda et al.(1985) to calculate heat fluxes from obtained data.

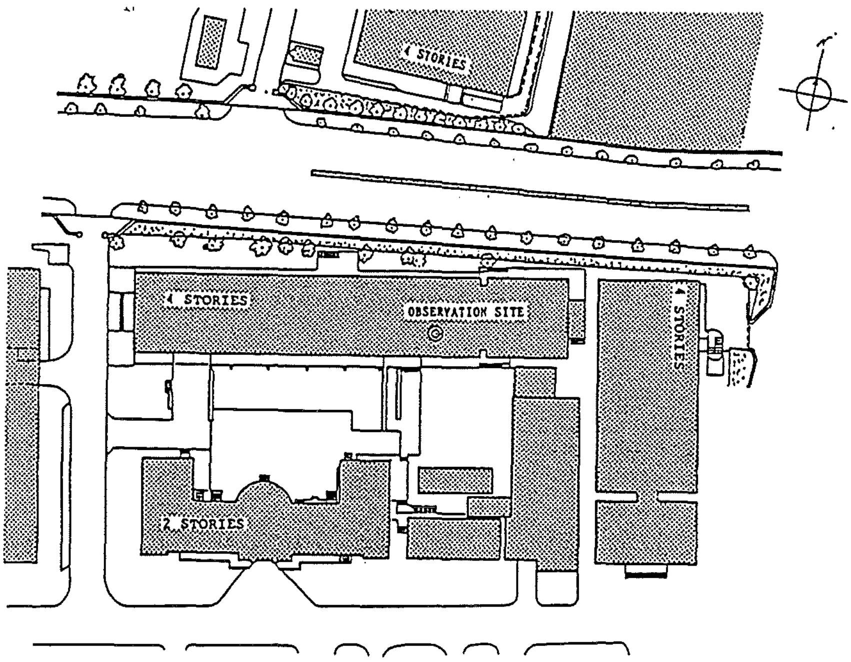


Figure 1 The observation site. Observation was carried out at the top of a four stories building which was 15.7m high. The heights of surrounding buildings were approximately the same.

Table 1 Summary of variables measured and instruments used.

VARIABLES	INSTRUMENTS	COMMENTS
wind velocity components (u, v, w)	3-D sonic anemometer	Kaijo, type: DA-600 probe: TR-61C
temperature fluctuation (θ')	thermo-couple	T-type ϕ=0.076mm
absolute humidity fluctuation (q')	infrared hygrometer	Kaijo, type: AH-300 probe: HGA-100
average of relative humidity (R.H.)	humicap	Kaijo, type: AH-300 probe: ST-70

The sensors were mounted on the top of a mast, which height is alterable from 1.8 m to 6 m shown in Figure 2. The measuring heights were set at 1.8 m, 3 m, and 6 m above the roof level which is 15.7 m from the ground.

The measurements were carried out in the following three time zones as the morning, the afternoon, and the midnight. Besides this, we measured at every one hour during the daytime.

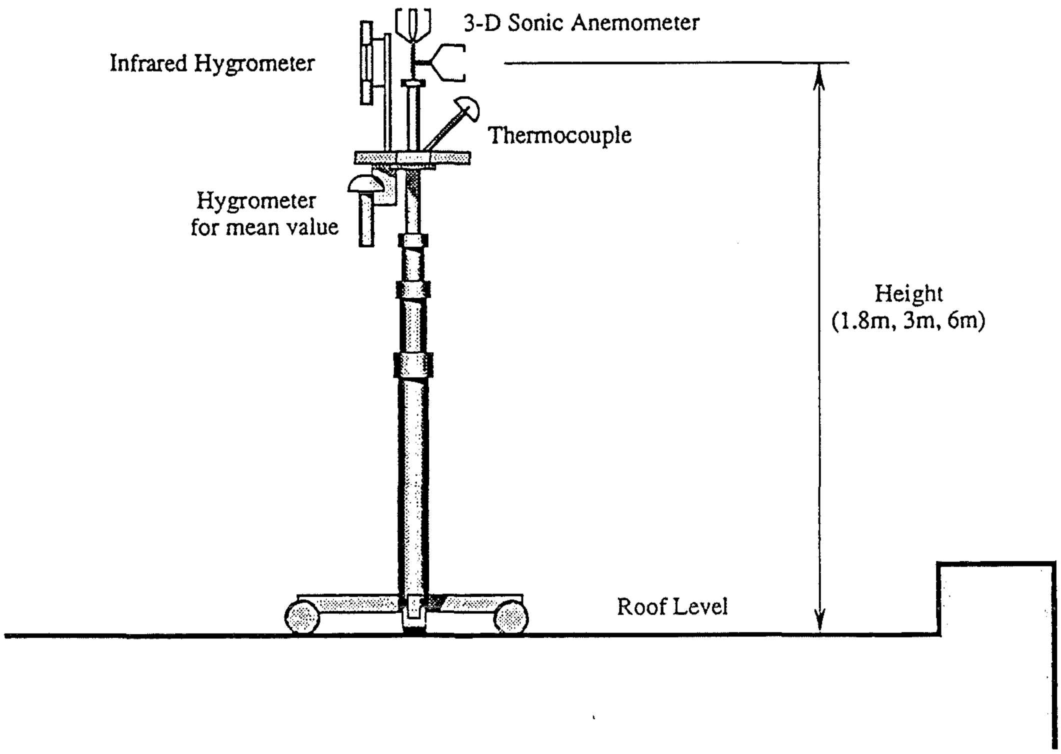


Figure 2 Schematic depiction of instrumentation. The sensors were mounted on the top of a mast which height was alterable from 1.8m to 6m. The measureing hights were set at 1.8m, 3m, and 6m above the roof level which was 15.7m from the ground.

Table 2 Equations for calculating heat fluxes. (after Satoda, H. et al., 1985.)

$$Q_H=\overline{\rho}C_{pd}\overline{w'T'}+\overline{\rho}(C_{pv}-C_{pd})\overline{T}\,\overline{w'q'}+\overline{\rho}(C_{pv}-C_{pd})\overline{q}\,\overline{w'T'}+\overline{\rho}C_{pd}\overline{w'T'^2}/\overline{T}-\overline{\rho}C_{pd}\overline{w}\,\overline{T'^2}/\overline{T} \quad \cdots (1)$$

$$Q_E=\overline{\rho}L\overline{w'q'}+\overline{\rho}L\overline{w'q'T'}/\overline{T} \quad \cdots (2)$$

$$\overline{\rho}=\frac{\overline{P}}{R_d(1+c\overline{q})\overline{T}} \quad \cdots (3)$$

$$\rho'=\overline{\rho}\left(-\frac{T'}{\overline{T}}-\frac{q'}{1+c\overline{q}}+\frac{T'^2}{\overline{T}^2}-\frac{\overline{T'^2}}{\overline{T}^2}\right) \quad \cdots (4)$$

Q_H : sensible heat flux Q_E : latent heat flux T : potential temperature q : specific humidity w : vertical component of wind velocity ρ : density of moist air R_d : gas constant of dry air C=0.622 C_{pd} : specific heat at constant pressure for dry air C_{pv} : specific heat at constant pressure for moist air L : latent heat of vaporization of water
(prime indicates the deviation from mean value)

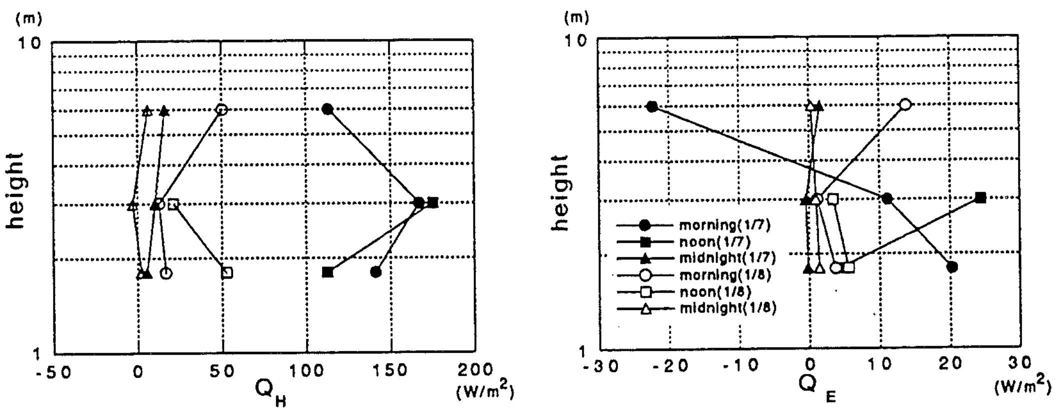
RESULTS

Figure 3 shows vertical profile of sensible and latent heat fluxes. During the daytime, heat fluxes are not constant at every height, and vertical differences existed. But during the nighttime, turbulent fluxes were small and similar at every height.

Figure 4 shows hourly variations of sensible and latent heat flux of every height. At 6 m height, the value of heat flux increases gently from morning to afternoon. On the other hand they grow suddenly before and after two o'clock in the afternoon at 3 m and 1.8 m heights.

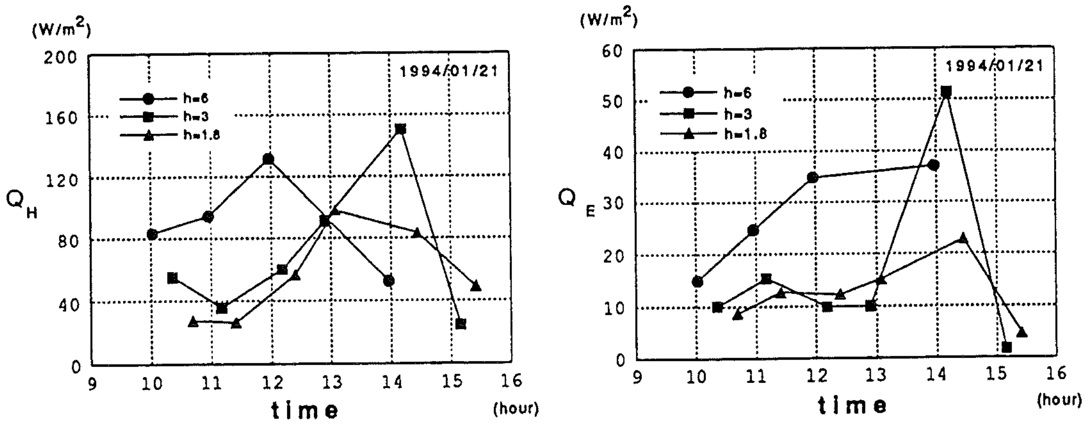
Figure 5 shows relation between the magnitude of the deviations (i.e. the root mean square difference) of vertical velocity and heat fluxes. There might be some correlations between them. It was an expected result because heat was transported by the convection of atmosphere and heat flux calculated from the fluctuations of eddy properties. There seems a tendency that the variances of the heat fluxes become more remarkable as the turbulent components of vertical velocity become large.

Figure 6 shows the relation between sensible and latent heat flux. The Bowen ratio (QH/QE) was nearly constant at each height. The mean value of the Bowen ratio at the height of 6 m, 3 m, and 1.8 m were about 5.42, 4.87 and 4.69 respectively.



(a)sensible heat flux (b)latent heat flux.

Figure 3 Vertical profile of heat fluxes; (a)sensible heat flux: (b)latent heat flux.



(a)sensible heat flux (b)latent heat flux.

Figure 4 Hourly variation of heat fluxes; (a)sensible heat flux: (b)latent heat flux.

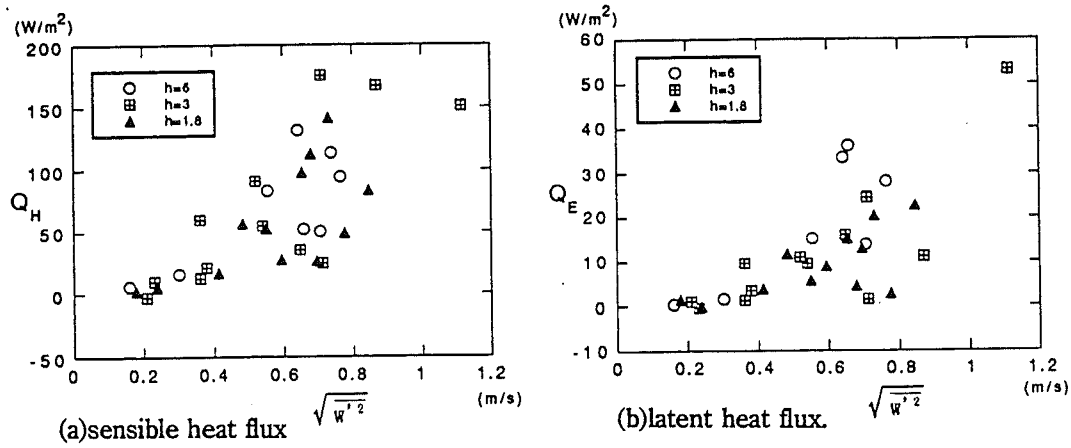


Figure 5 Relation between the magnitude of the deviations of vertical velocity and heat fluxes.

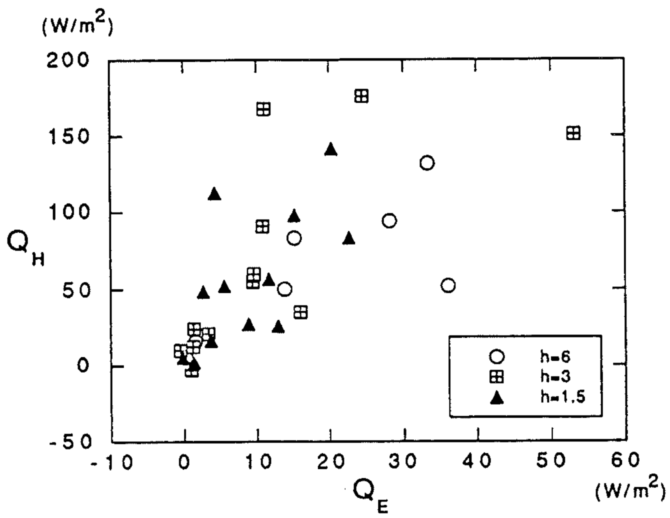


Figure 6 Correlation of sensible and latent heat flux. The mean value of the Bowen ratio at the height of 1.8m, 3m, and 6m were about 4.69, 4.87, and 5.42 respectively.

In conclusion: 1) there are some correlations between turbulent velocities and heat fluxes; 2) during the daytime, vertical differences of turbulent fluxes existed; 3) during the nighttime, turbulent fluxes were small and similar at every height; 4) the Bowen ratio was nearly constant at every height.

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URBAN PRECIPITATION PATTERNS IN THE RHINE-RUHR-AREA

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ABSTRACT

Low spatial representativity of point measurements has been found by statistical analysis of precipitation data in complex structured urban areas. Correlation between precipitation modifications and local land use parameters are identified, which suggests that boundary layer effects have large influences. The urban effects on the FLETCHER-Equation are modelled by a statistical approach.

1. DO CITIES EFFECT RAINFALL?

Since the *METRO*politain *M*eteorological *EX*periment (*METROMEX*) was performed at St. Louis (USA) there is not much doubt that major urban areas affect rainfall [1-29]. However, for complex structured urban areas like the Rhine-Ruhr-Area (*RRA*) the different components of urban impacts are difficult to identify. Here, rainfall data analyses show very small spatial representativity of point measurements: the precipitation patterns are not homogeneous at very small scale.

2. PRECIPITATION PATTERNS AND URBAN WATER MANAGEMENT

The results of many investigations on urban precipitation modifications like *METROMEX* have shown an increase of storm frequencies. Increases of thunder storm frequencies have also been found in the *RRA* by various authors [e.g. 30, 31].

As a part of the research project "*Improvements in Urban Hydrocycles for Soil and Groundwater Protection*" at the University of Essen, it is necessary to improve the understanding of precipitation modifications in the *RRA* for water budget calculations, the design of drainage systems and monitoring networks.

3. WHAT ARE THE MAIN PROCESSES?

Theory yields two main pathways by which man may affect precipitation patterns: cloud physics and boundary layer effects. Most investigations like *METROMEX* generally neglected the modifications of rainfall passing boundary layer but in the *RRA* there is great statistical evidence that droplet selection by boundary friction and falling droplet evaporation are important processes creating microscale precipitation patterns closely attached to the land use. Furthermore, the local thermal pattern shows an effect as great urban heat island intensities are attached over convective regimes to a second daily precipitation maximum during early morning hours (Figure 1).

The identification of precipitation regimes is undertaken using mean monthly precipitation averages (1951-1980) of 302 stations in North-Rhine-Westphalia and applying Complete Linkage Cluster Analysis for pattern recognition. Discriminancy Analysis shows that the separation may be induced by topographical height and urbanity. Correlation Analysis of EUCLIDian distance to the centroid of the rural cluster and land use measures shows highest bivariate coefficients for geographical distances of less than 2 km. This means urban precipitation regimes are mainly produced by their very local environment. However, annual precipitation sums of elements of the urban cluster lie over the confidence interval of the rainfall-height-regression of rural cluster elements. This means there is evidence that urban stations receive significantly more rainfall.

Processes based on the emission of nuclei show no significant effect. A day-of-week variation of rainfall [see 32-39] has been detected by spectral analyses but seems to be based on the day-of-week variation of Northern Atlantic and European circulation patterns (Figure 2).

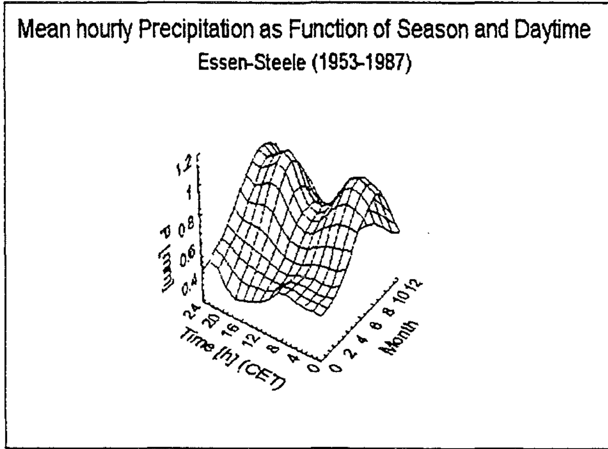

Fig. 1: The *Urban Heat Island Effect* is producing a local mainly nocturnal atmospheric instability. The analyses of 5-min precipitation data of 28 monitoring stations in the RRA show that this has an effect on the mean daily precipitation distribution. For analysis the sinus shaped regression functions with one and two daily maxima have been used for parameter estimation using non-linear estimation. The correlation coefficients are used for a ranking of stations from best fit to two maxima to best fit to one maximum. This ranking shows a SPEARMAN-Correlation of 0.86 to the ranking of urban structures from low to high potential intensity of the *Urban Heat Island.* 3-dim data analyses show that the second maximum occurs mainly in the early morning hours during the seasons with high heat island intensities.

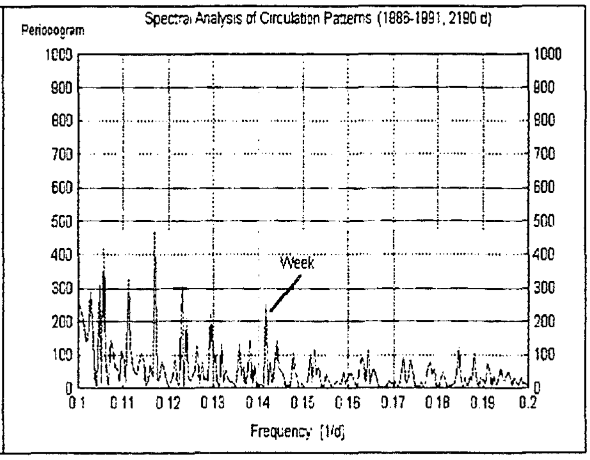

Fig. 2: In many data sets a day-of-week variation of rainfall is found by Spectral Analyses also in the *RRA*. The classical approach of interpretation is that this is a result of the working day/weekend variation of human activities like emission of nuclei and vapour. However, a Spectral Analysis of the circulation patterns over the Northern Atlantic also shows a peak at 0.14 1/d (7 day period): It seems evident that this "background" variation is the reason for precipitation variation. Whether this is man made or not is still open [see 40].

Modelling the Urban Effect on the FLETCHER-Equation

One result is that point rainfall data in the *RRA* has very low spatial representativity of about 2 km. In practice there are only very few data sets available for the calculation of design curves used in urban hydrology. In the usual case in which a usable monitoring station is at more than 2 km distance, the data has to be adjusted, taking into account thermal and frictional conditions. For this purpose a multidimensional Regression Model of the FLETCHER-Equation [41] representing the maximum precipitation $P_{max,5}$ as a function of the duration D

$$P_{\max,5} = aD^b \qquad \text{with } b = 0.5 - 0.03a$$

has been calibrated using 5 years à 5-min data of a high density monitoring network and land use structures with low collinearity. Using this method the modifications of the FLETCHER-Equation may be regionalised to approximately 60% of the *RRA* (Figure 3).

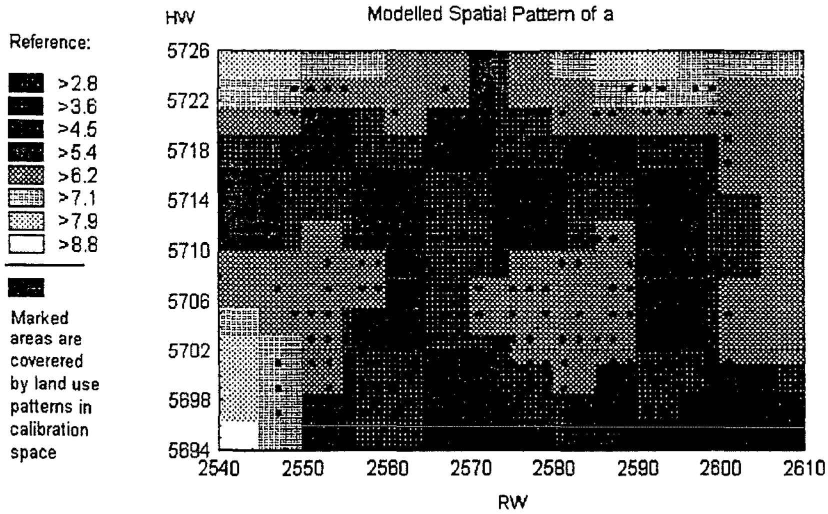

Fig. 3: The rather small spatial representativity of point measurements also exists concerning storm precipitation equations. Statistical analyses of five years data à 5-min show that frequencies and heights of intensive rainfall events vary significantly over low geographical distances of less than 2 km. For civil engineering this means design curves have to be adopted to the local conditions of a site. For this purpose a statistical multipe-linear regression model between the FLETCHER-Equation and the local land use conditions has been calibrated with R^2=0.76. This *M*odel for *A*rea *R*ainfall in *C*omplex *U*rban *S*tructures (***MARCUS***) may be applied on the conditions found in approx. 60 % of the *RRA*.

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URBAN WORKING-DAY/WEEKEND VARIATIONS OF CLIMATIC ELEMENTS WITH FOCUS ON HEAVY SUMMER RAINS

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ABSTRACT

During 5 summers, precipitation was differentiated according to amount and frequency of rain types in Heidelberg-Ziegelhausen, Germany. The weekly curves (measured along a road with heavy traffic) follow the maxima and minima of CO and NO_2 concentrations, partly parallel, partly after one day (see diagrams).

First hypothesis: Partly burnt gasoline is exhausted, the gas contains some solid aldehydes.

Second hypothesis: NO_2 contacts with water vapor and forms an acid. When organic rests are added (i.e. benzol from car motors), the condensation runs 4 times more quickly.

1. INTRODUCTION

It is difficult to reveal [by direct measurements] the processes between a mixture of pollutants and the "natural" atmosphere. The known reactions are described by *HOBBS* (1993). A simple method is to compare meteorologic data of working days and weekend, first applied by *ASHWORTH* (1929) for precipitation. Yet, let us begin with other climatic elements.

NAKAMURA et al. (1994, see in this volume) compared wind speed in a Japanese city: On a normal working day it was 4.2 m/s, on a holiday without any economic activity it dropped to 3.5 m/s, while sun radiation rose from 12.5 to 15 MJ.

MITCHELL (1961) investigated the urban heat island of New Haven, Connecticut. It was most intensive from Tuesday until Saturday, but weak at Sundays. In more recent time, the weekly variation was reversed: Heat islands are most frequent and intensive on weekend nights and after Monday. This is due to the change of pollution type, from soot, dust and SO_2 to NO_x, benzol, water vapor, etc. When hard coal (anthracite) is burnt, no H_2O is emitted. When 16 g methane (1 Mol CH_4) are burnt, chimneys and pipes exhaust 36 g water vapor. Organic material, which is not completely burnt, influences the climate even more (see section "hypotheses").

The warm and polluted city air affects nearly all types of *clouds*, especially fog and cumuli. During the summer months, the sky above Mannheim, Germany, is partly covered by clouds at midnight (fig. 1): Thursday/Friday about 60 %, Sunday/Monday 40 % (average). Under a clear sky, rural surfaces cool quickly at night, the city temperatures are relatively mild. On weekends, when the sky is less clouded, sun radiation helps to produce *ozone*; the daily maxima of Mannheim-Rheinau rise slowly from 54 $\mu g/m^3$ on Tuesday to 56 on Friday, but jump to 63.5 $\mu g/m^3$ on Sunday (after *MAYER* et al. 1993, see my fig. 1).

2. PRECIPITATION

For decades of years, the effect of cities and their pollution on the spatial and temporal variation of precipitation was discussed. Several researchers tried to compare working-day/weekend amounts, and received different results. *SIMMONDS & KAVAL* (1986, 121) criticize too short observation periods and recommend tests to prove statistical significance.

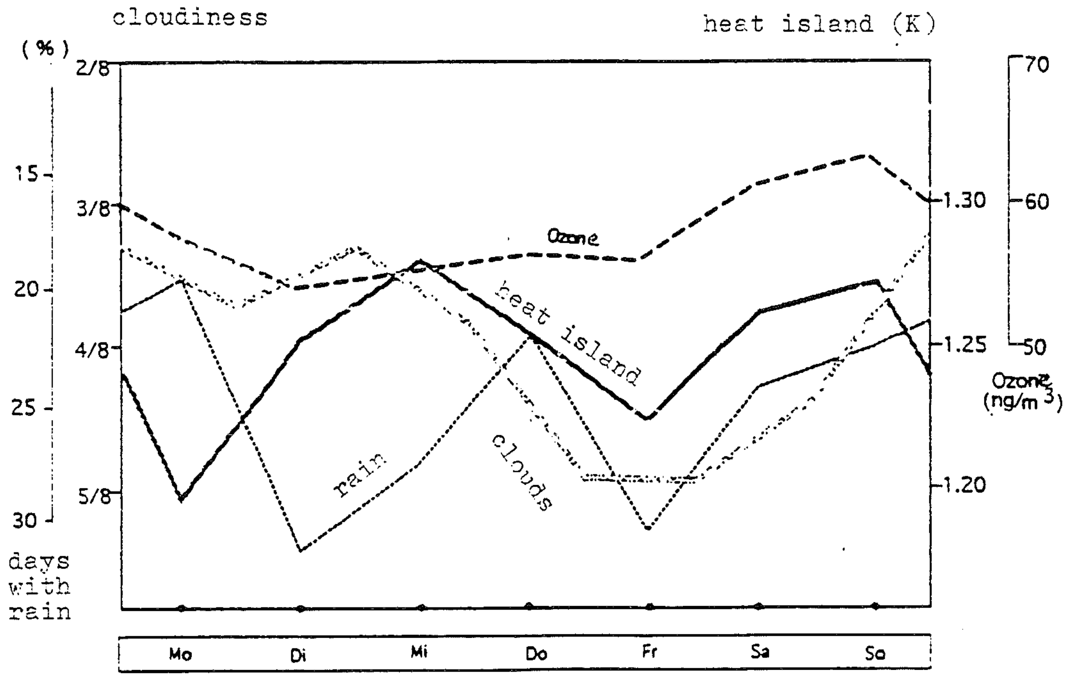

Fig.1 : Weekly variation of ozone in Mannheim (1980 - 1992, *MAYER* et al. 1993). Heat island of Berlin (summer 1893 - 1980, *HELBIG* 1987). Cloudiness in Mannheim (7 summer months of several years, midnight). Days with rain over 1 mm in Heidelberg May - September 1989-1991 (from *FEZER* 1994/95).

All authors (i.e. *JAUREGUI & KLAUS* 1982, 281) who studied *heavy rains*, found similar results: Frequency and amount increase from Monday to Friday. Heavy showers and thunderstorms find public interest, because they endanger people and cause severe damages. During a heavy rain in Stuttgart in July 1972, 6 persons were drowned in their cars, when they were blocked in a flooded subway. On November 2nd, 1977 (a Wednesday, see fig. 2) less than 25 mm of rain fell in rural Greece, but 165 mm in the center of Athens; 100 mm fell within 2 hours and 24 people were killed (*FLOCAS & GILES* 1979).

3. USED DATA

My rain gauge is situated at the eastern end of Heidelberg; this is the downwind side at daytime. The air quality station, run by the "Landesanstalt für Umweltschutz", is situated beside a high-traffic road on the western edge of the city. The concentrations of the pollutants at 3 p.m. are published. In fig. 2, the march of carbon monoxide (CO) reflects the traffic density. During 5 summers, from May to September each, precipitation was differentiated according to amount and frequency of rain types.

4. WEEKLY MARCH OF RAIN TYPES

Rain at *Sundays* is moderate in frequency and amount. Car traffic on the western edge of Heidelberg is only 70 % of working-day average, before noon it is even less. This seems to be important: No rush-hour augments the gas concentration over a presumed threshold. The concentration of nitrogenous oxides is reduced to 53 %. This means that other NO_x sources are lowered even more

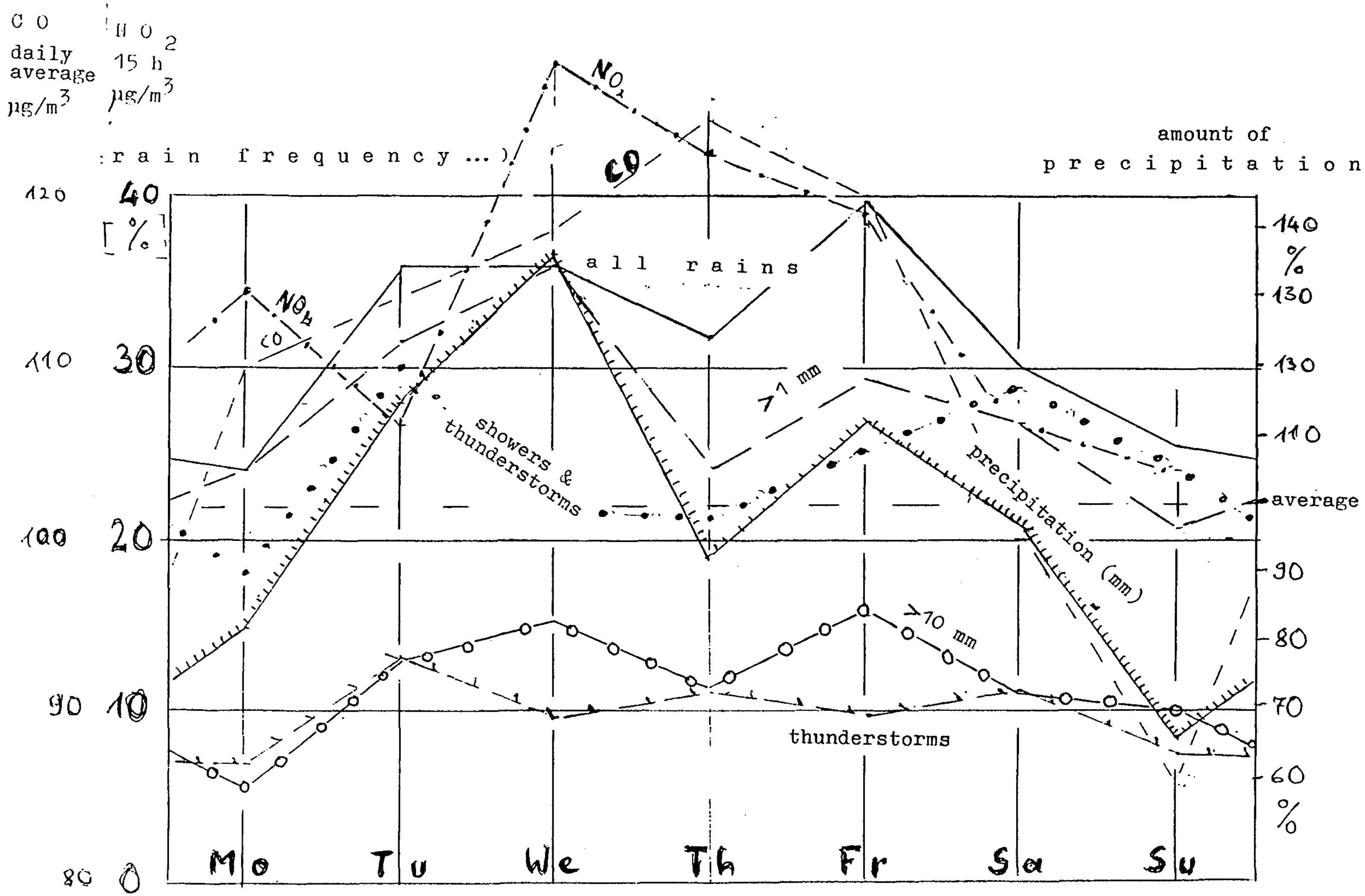

Fig.2 : Frequency of different rain intensities (mm/day) in Heidelberg-Ziegelhausen during 5 summers (May-September 1989-93), related to traffic immision at LfU station.

compared to car traffic. On *Monday*, CO concentration rises from 6 to 30 mg/m^3, NO_2 from 25 to 34 µg (fig. 2). In the morning, the "normal" working-day traffic is augmented by students, agents, service teams, etc.. The rain frequencies rise only on Tuesday. This may be explained by slowly running chemical processes. Not the primary pollutants, but the secondary ones favour the condensation of water vapor and finally trigger a rainfall. Dense traffic on Monday causes the tightest cloud cover on the following days (fig. 1). On 35 % of all *Tuesdays* rain falls, especially showers (fig. 2). Thunderstorms are most frequent. The peak of the precipitation amount follows one day later: 35 % more than the weekly average. On *Wednesday* and *Thursday*, frequencies and amount (mm) stay on a high level. Nitrogenous oxides reach a maximum. The effect is a maximal frequency of all types: 39 % of all *Fridays* are wet, especially heavy rains often fall.Parallel to the reduced CO and NO_x concentrations, nearly all types of rain are a little rare at *Saturday* and *Sunday*; only the showers are frequent, but they bring less rain than on weekdays.

If somebody plans an outdoor activity, Monday offers the best chances, but no guarantee for dry weather. It is important to note, that all figures and curves given here are probability values. In a special barometric constellation rain may fall. The shower, which flooded the Schwarzbach valley and destroyed hundreds of houses, shops and factories, occured on June 27, 1994; this was a Monday. The factors which vary the precipitation during a week, are strongest in cities and along overland highways. But they affect the climate of the surrounding countryside, too. Even in Elsenz, a village in 10 km distance to the next highway, the weekly march was similar to the described variation.

5. HYPOTHESES

When 1 kg of petrol or its refinery products is burnt, a small part of it is not oxidized completely. 240 mg of aldehydes are emitted. The longer aldehyde molecules are not liquid but solid, so they favour condensation of water vapor. Another hypothesis deals with nitrogenous oxides which are connected with molecules of water vapor to nitric acids. When organic molecules (e.g. benzol from car exhaust pipes) are added, condensation runs 4 times more quickly.

Both hypotheses need some more investigation, practical measuring as well as laboratory experiments. But my final appeal is well founded: Planners and politicians, industry and private persons should test all possible measures to reduce car traffic.

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DIFFERENCE OF URBAN EFFECTS OF CLIMATE IN KYOTO CITY BETWEEN A WEEKDAY AND A HOLIDAY

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ABSTRACT

As well known, the intensity of a heat-island is strongly relevant with the urban zoning. This fact obviously suggests of a contribution of human activity towards the heat-island phenomenon. Its procedures, however, still have a large extent to be discovered.

The object of this study was to seek for a guideline to this elucidation. We had chosen two (2) survey points within a city; a point located in a commercial area and a point located in a residential area. The commercial area is sited by a road with heavy traffic on weekdays and fewer traffic on holidays: while the residential area possesses a road with fewer traffic throughout a week. At each point, temperature and humidity of the atmosphere were examined, on a weekday and on a holiday.

Between these two points, climatic difference was greater on a weekday than on a holiday, suggesting a strong intension of automobile traffic and other human activities (such as heat exhaust from air-conditioning in buildings) effecting the urban climate.

1. SURVEY

1.1 SURVEY SITES AND THEIR LOCATION

The location of the survey points, both in Kyoto city, are shown on Figure 1: the detailed surroundings of each point are shown on Figures 2(a) and 2(b).

Figure 2(a) indicates the survey point in a commercial area, with a principal road nearby. We had set up the point 1.5 meters away from the road, on a concrete tiled sidewalk. (described as 'site A' hereafter)

Figure 2(b) shows the point sited on the campus of Kyoto University. It is located in a residential area, also provided with a principal road nearby. The point was prepared on an asphalted surface.(described as 'site B' hereafter)

The two points are approximately 3.5 kilometers away from each other.

1.2 METHOD

At the site A, temperature and humidity were observed by Assman aspiration psychrometer, which was set at the height of 1.2 meters using tripod. The device was shaded from sunbeam.

At the site B, data were examined the same way with one exception; the measuring device was an automatic apparatus set upon a rooftop. The observed data were later adjusted to that on a ground level.

1.3 TERM

The first survey was carried out on 14 August 1992, every 30 minutes from 7:00 until 19:00. This date of a year is a typical holiday in Japan, when the minimum amount of car-traffic is observed in Kyoto city.

The second was carried out on 2 September 1992, also every 30 minutes during the same hours. It was a normal weekday with the standard amount of car-traffics.

2. RESULTS

2.1 RESEMBLANCE OF THE CLIMATE ON BOTH DAYS

Figure 3 indicates the temperature, the water vapor pressure, and the global solar radiation observed at a observatory in Kyoto University. Figure 4 shows the wind direction and velocity at the same point. Both figures are provided to compare the general climate on a weekday with that on a holiday.

The accumulation of the global solar radiation was 12.5 MJ/m² on a weekday, while 15.3 MJ/m² on a holiday; the maximum solar radiation 1.0 kW/m² on a weekday to 0.83 kW/m² on a holiday; the average daytime (7:00-19:00) temperature 29.7 °C to 30.6 °C; the maximum temperature 32.2 °C to 33.3 °C. The wind direction changed from north-east to south-west at 8:00 on both days. The wind velocity kept on increasing from 8:00, and started dropping after the sunset.

These resemblances may allow one to compare the acquired data between both days.

2.2 TEMPERATURE

Figure 5 shows the rise of the temperature at site A compared to site B. The average rise on a weekday was about 2.2 °C , which is 1.3 times of that on a holiday.

2.3 WATER VAPOR PRESSURE

The rise of water vapor pressure at site A compared to site B is shown in Figure 6. On a weekday, the average rise was approximately 1.6 mmHg, which means 2.3 times of that on a holiday.

3. CONCLUSIONS

3.1 COMPARISON BETWEEN THE SITES A AND B

Both the temperature and the water vapor pressure were always higher in the commercial area than in the residential area; this was common through the term of survey. It confirms the 'urban effect', which suggests a higher temperature and water vapor pressure in a commercial area due to the urban structure, the heat exhaust from air conditioning in buildings, and the amount of car-traffic.

3.2 COMPARISION BETWEEN THE WEEKDAY AND THE HOLIDAY

Although the rise of the temperature and the water vapor pressure at site A compared to B were always positive, it did not show the same value on the weekday and on the holiday; Figures 7 and 8 indicate this fact. The rise of the water vapor pressure was especially high on the weekday (see Figure 6; the coordinates of thick line on the left are drawn higher than that on the right).

Considering the height of the survey sites, which were at the ground level, this extreme rise of the vapor pressure may due mainly to the exhaust gas from car-traffic rather than from air-conditioning; the rise may be hardly influenced by the air-conditioning, since a cooling tower is usually installed on the top of the building.

3.3 FURTHER EXTENSIONS

The above conclusions are casually and fortunately found. We therefore have not made enough survey to define the ratio of each factors, and cannot determine the amount of each contribution.

A further investigation is now being made to clear this point.

REFERENCE

Stull, R.B.: An Introduction to Boundary Layer Meteorology, Kluwer Academic Publishers, 1992

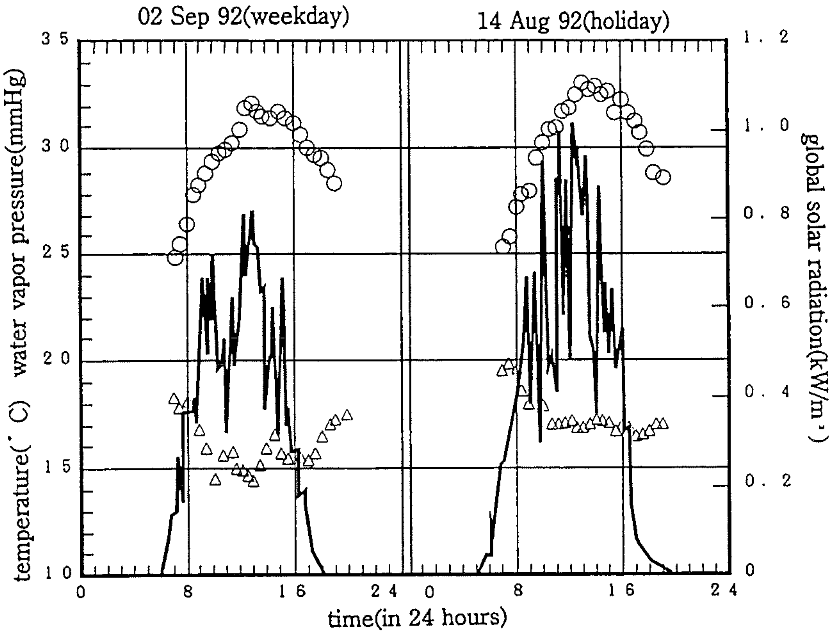

Fig.3 The climates observed on a weekday and a holiday

○ : temperature
△ : water vapor pressure
— : global solar radiation

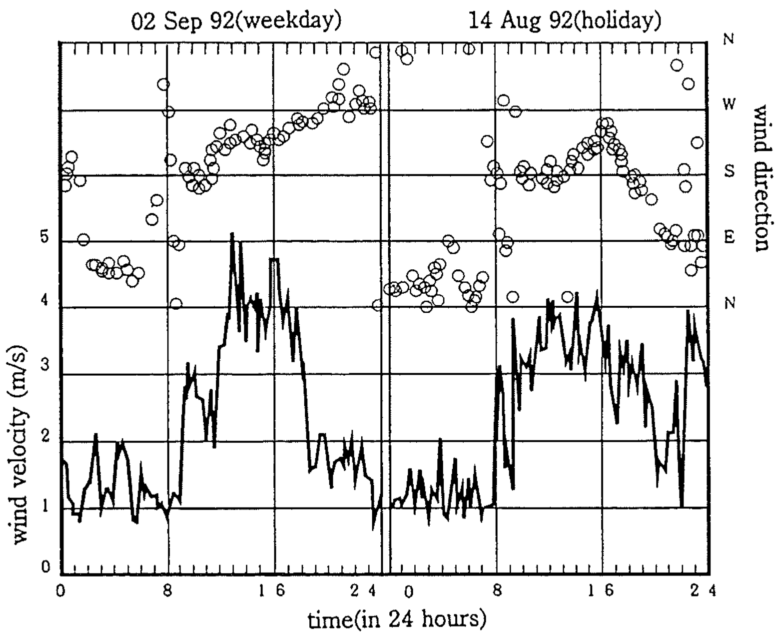

Fig.4 Wind direction and velocity on a weekday and a holiday

○ : wind direction
— : wind velocity

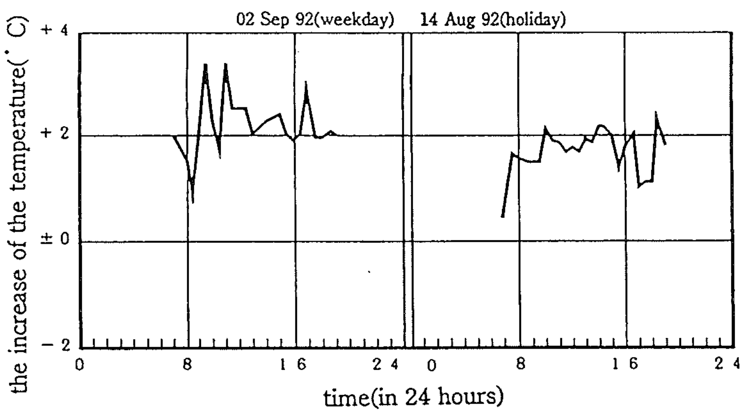

Fig. 5 the temperature at site B was subtracted from the simultaneous value at site A

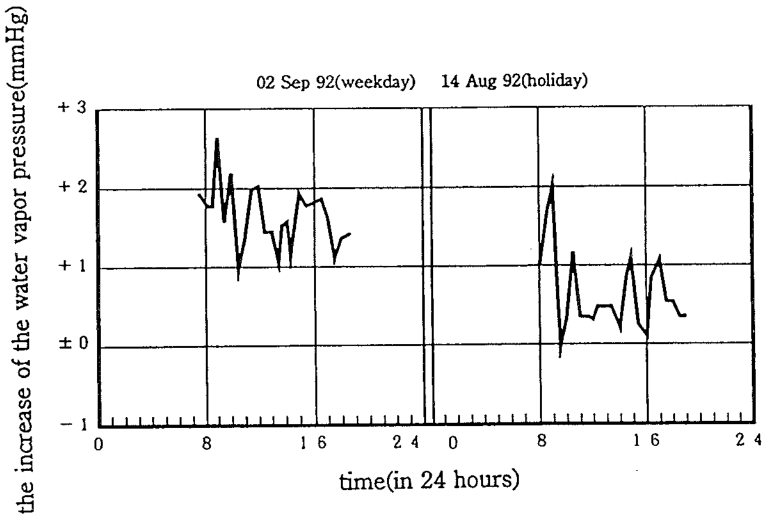

Fig. 6 the water vapor pressure at site B was subtracted from the simultaneous value at site A

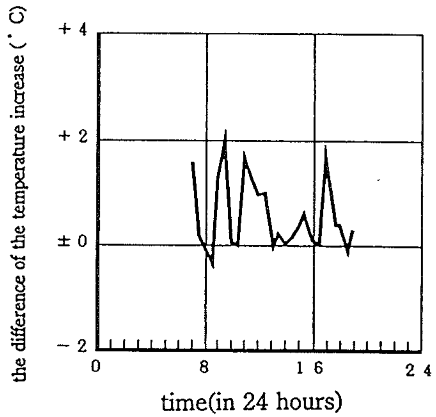

Fig. 7 the difference of the temperature increase; the rise of the temperature on the holiday was substracted from that on the weekday

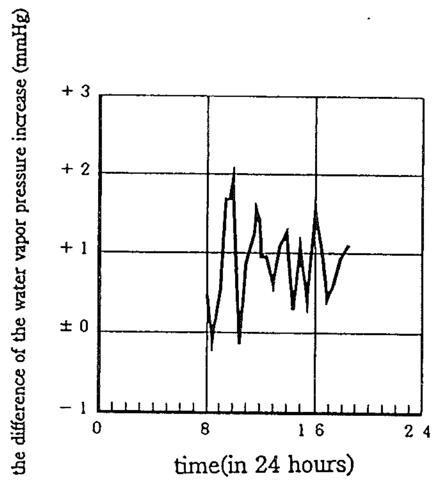

Fig. 8 the difference of the water vapor pressure increase; the rise of the water vapor pressure on the holiday was substracted from that on the weekday

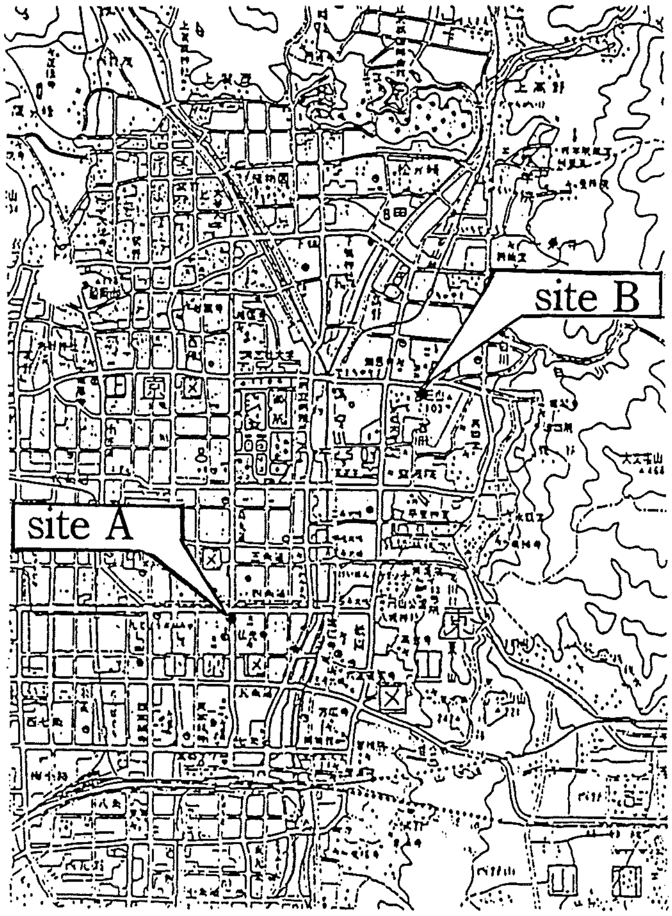

Fig. 1 site A is located in the city center of Kyoto, while site B is in the down town

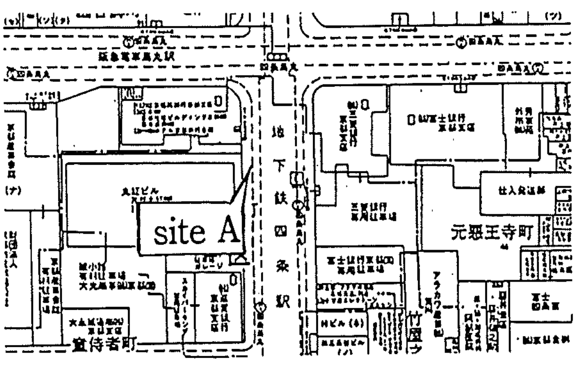

Fig. 2(a)

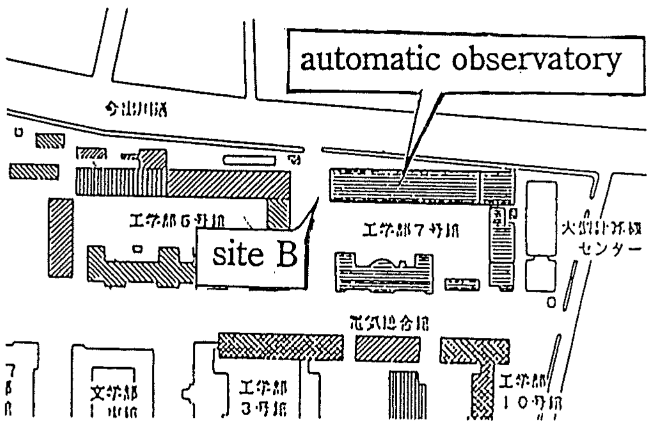

Fig. 2(b)

site A surrounded with commercial buildings

site B and the automatic observatory in the university

FIELD STUDY ON GREEN CANOPY AS URBAN COOL-SPOT

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ABSTRACT

Some sets of meteorological elements measurements were carried out to clear a thermal effect of green canopy "Cool Spot" in an urban area. The aim of this study is to collect fundamental data to propose this "Cool Spot" as a unit of an urban environmental planning.

The aim of the measurements can be divided into three groups. One is to measure meteorological elements in and around a large urban park (run 1, 2). In spite of a high wind (max. about 2.5 m/s in the street), ΔT_{g-u} was measured between 0.4 °C - 1.9 °C in daytime, 0.7 °C - 1.3 °C in the evening. Second is to compare with urban built-up area and large urban parks in Osaka (run 3 - 6). $\Delta T_{g-u, max}$. was 2.5 °C in the early morning, 1.8 °C in daytime. $\Delta T_{g-u, min}$. was 1.1 °C in the early morning, 1.1 °C in daytime. Third is to measure a thermal effect of small urban green canopies (run 7, 8). In run 7, ΔT_{g-u} was -0.5 °C - 0.9 °C in daytime. Comparing with the small urban park and the surrounding area in run 8, ΔT_{g-u} was 0.4 °C - 0.5 °C in daytime.

1. INTRODUCTION

In summer daytime, the space where covered by large green canopy and its air temperature is lower than its surroundings can be recognized. This phenomenon is established when green canopy shades ground from solar radiation and the latent heat of evaporation at a leaf cool the air temperature around the green canopy. Here, we call this space "Cool Spot ". Since the increase of ratio of urban artificial surface brings the increase of amount of stored heat and this is regarded as one of the causes of change in an urban thermal environments, this "Cool Spot" is expected to relieve the urban thermal environment when it is arranged attentively. The aim of this field study is to collect fundamental data to propose this "Cool Spot" as a unit of an urban environmental planning. Some sets of meteorological elements measurements were carried out in and around urban parks in Osaka in August 1992 to clear a thermal effect of green canopy.

2. SURVEY AREA

Osaka (Long. 135° 30' E, 34° 41' N.L.) lies almost in the center of Japan (fig.1). The elevation is 0 - 20 m above sea level. Osaka is bounded by the Osaka Bay in the west and by range of mountain in the east and south (fig.2).

Fig.1. Location of Osaka (I)

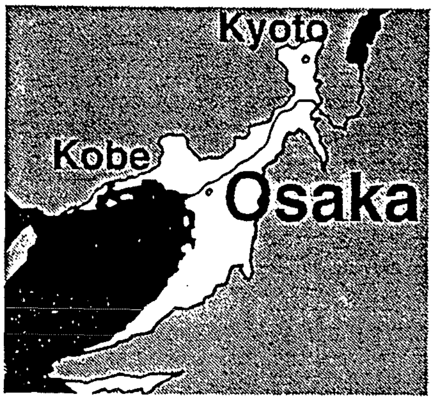
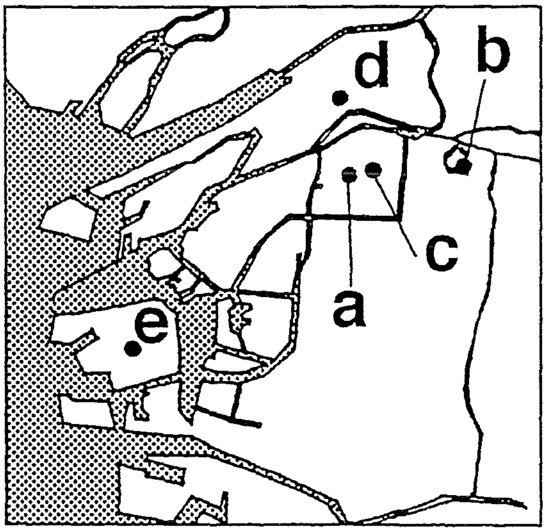


Fig.2. Location of Osaka (II)

In this research, four urban parks surrounded by a built-up area were studied (fig.3). A scale of these parks are shown in Table 1.



a: Utusbo Park b: Osaka Castle Park c: Hon-Machi Area
d: the Promenade along Ume-Shine: Nanko Port Town Park

fig.3 Survey Area in Osaka

Table 1. Scale of the Surveyed Urban Parks

	Osaka Castle Park	Utusbo Park	Promenade Ume-Shin	Port-Town Park
area	108 ha	19 ha	0.9 ha	10 ha
min. Width	860 m	140 m	30 m	62 m

Trees in these parks are 12-15 meter high and cover wide area.

As a reference of a built-up area, measurement have carried out in run 3 - 6 in Hon-Machi; the center of Osaka.

3. DATA COLLECTION METHOD

This research was consisted of eight sets of measurements. At each measurement, four points to measure were selected beforehand. Researchers walked from the first point to the fourth point, and then backed to the first point again. The first and the final data of each measurement were used to correct the data as it measured at the standard time to enable to compare. The time required to finish each measurement was about 45 - 75 minutes on the average. The meteorological elements we measured and the equipments we used are shown in Table 2.

Table 2. Measured Meteorological Elements and Equipments

measurement item	measuring instruments
air temperature	wet-dry-bulb thermometer
humidity	wet-dry-bulb thermometer
surface temperature	infrared radiation thermometer
wind velocity	three-cup anemometer

4. RESULTS

Meteorological elements observed at the Osaka Meteorological Station in August 1992 is shown in fig. 4. From the evening in 17 to 19 in August, a typhoon passed in the north of Osaka. At that time rain fall was observed at the Osaka Meteorological Station. Another rain fall was measured 2.5 mm in 22 August late in the evening. Except these days, rather high solar radiation and high air temperature were observed at the survey area in daytime.

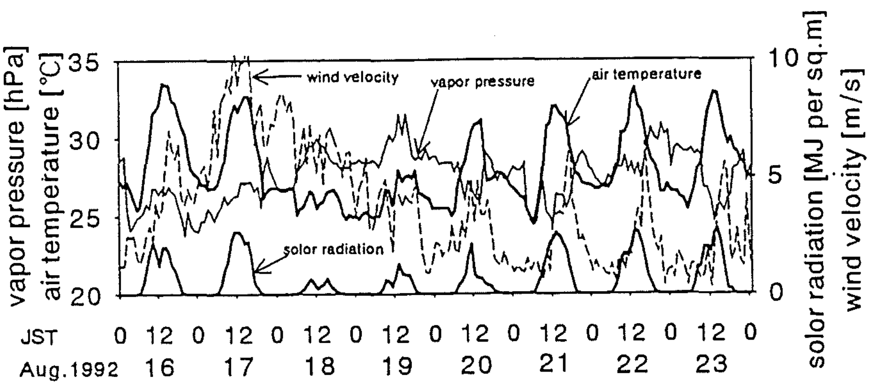


Fig. 4. Meteorological Elements observed at Osaka Meteorological Station, 16 - 23 August 1992

The aim of the research can be divided into three groups. One is to measure meteorological elements in and around a large urban park (*Utusbo Park*), (run 1, 2). Results of run 1 and 2 are shown in Table 3. In spite of a high wind (influenced by typhoon, max. wind velocity was about 2.5 m/s in the street), the green canopy-urban temperature differential; $\Delta T_{g\text{-}u}$ was measured between 0.4 - 1.9 °C in daytime, 0.7 °C - 1.3 °C in the evening.

Second is to compare with an urban built-up area (Hon-Machi, Osaka) and large urban parks (Utusbo Park and Osaka Castle Park), (run 3 - 6). Results of run 3 - 6 are shown in Table 4. $\Delta T_{g\text{-}u,\ max.}$ was measured 2.5 °C in the early morning, 1.8 °C in daytime. $\Delta T_{g\text{-}u,\ min.}$ was 1.1 °C in the early morning, 1.1 °C in daytime.

Table 3. Results of Measurement in Large Urban Park and Surroundings

item		Utusbo Park	street A*4	street B*5	street C*6
noon *1					
mean air temp. ℃		32.0	32.4	33.9	33.4
ΔT*2 ℃		0.0	0.4	1.9	1.4
mean surface temp. ℃	ground	31.9	44.8	48.8	46.7
	wall	-	39.2	47.5	37.8
	leaf	31.7	-	-	-
mean RH %		62.1	56.7	50.1	55.1
mean wind v. m/s		0.6	2.1	1.0	1.9
evening *3					
mean air temp. ℃		29.1	29.8	30.0	30.4
ΔT*2 ℃		0.0	0.7	0.9	1.3
mean surface temp. ℃	ground	27.6	33.4	35.2	36.0
	wall	-	32.8	31.7	33.0
	leaf	28.7	-	-	-
mean RH %		72.3	66.7	65.5	69.7
mean wind v. m/s		0.8	1.3	0.9	0.9

*1: run 1 17. Aug. 1992 13:30 - 15:50 JST fine *2: compare with the air temp. observed in Utusbo Park
*3: run 2 17. Aug. 1992 18:00 - 18:47 JST fine *4 - *6: surrounding built-up area, distance (m) from the boundary of Utusbo Park

Table 4 Comparison between Urban Built-up Area and Large Urban Parks

item		Utusbo Park	built-up area Honmachi*1	Osaka Castle Park
early morning*2				
mean air temp. ℃		24.1	26.5	25.0
ΔT *3 ℃		-2.4	0.0	-1.6
mean surface temp. ℃	ground	24.6	26.7	24.3
	wall	-	26.3	-
	leaf	24.5	-	24.3
mean RH %		92.5	79.5	83.3
mean wind v. m/s		0.0	0.6	0.0
noon *4				
mean air temp. ℃		29.9	31.1	29.3
ΔT *3 ℃		-1.2	0.0	-1.8
mean surface temp. ℃	ground	31.1	39.8	28.2
	wall	-	32.2	-
	leaf	30.5	-	29.7
mean RH %		64.9	60.3	67.7
mean wind v. m/s		0.9	1.3	0.6

*1: the central business area in Osaka City. *2: average value of run 4 and run 6
run 4: 21. Aug. 1992 05:00 - 05:45 JST cloudy, run 6: 22. Aug. 1992 05:00 - 05:45 JST cloudy
*3: difference in air temp. (comparison with urban built-up area). *4: average value of run 3, run 5 and run 7
run 3: 20. Aug. 1992 12:50 - 14:35 JST cloudy. run 5: 21. Aug. 1992 12:30.-.14:15 JST fine
run 7: 22. Aug. 1992 12:30.-.14:15 JST fine

Third is to measure a thermal effect of small urban green canopies (*the Umeda Promenade* and *Nanko Port Town Park*), (run 7, 8). Results of run 7 and 8 are shown in Table 5 and Table 6, respectively. In run 7, the measurement around green covered promenade, $\Delta T_{g\text{-}u}$ was -0.5 - 0.9 °C in daytime. Comparing with the small urban park and the surrounding area in run 8, $\Delta T_{g\text{-}u}$ was 0.4 °C - 0.5 °C in daytime.

Surface temperature under the green canopy were always cooler than other measurement points. The tendency that the wind velocity measured lower under the green canopy was recognized.

Table 5 Results of Measurement in a Small Urban Park and Surroundings (I)

item		promenade *1	street crossing	on pedestrian birdge *2	opposite side of promenade
mean air temp. ℃		32.5	33.4	32.2	32.0
ΔT *3 ℃		0.0	0.9	-0.3	-0.5
mean surface	ground(sunny)	42.4	47.7	45.6	47.1
temp. ℃	ground(shade)	30.2	-	48.4	46.4
	leaf	31.6	32.6	33.0	31.0
	wall	30.9	-	33.6	41.4
mean RH %		56.0	53.6	56.8	56.0
mean wind v. (m/s)		1.3	1.8	2.5	1.3

*1: the promenade along Umeda-shin-Michi avenue was covered by 15 m high trees
*2: pedestrian bridge over National Road 2, about 6 m above the ground level
*3: comparison with the air temp. under the green canopy along the promenade
run 7 22. Aug. 1992 12:15 - 13:17 JST fine

Table 6 Results of Measurement in a Small Urban Park and Surroundings (II)

item		park	bare ground	motor parking
mean air temp. ℃		29.8	30.2	30.3
ΔT * ℃		0.0	0.4	0.5
mean surface	ground(sunny)	41.5	44.8	56.1
temp. ℃	ground(shade)	29.2	-	-
	wall	-	30.3	33.0
	leaf	30.2	-	-
	water surface	32.0	-	-
mean RH %		67.5	65.0	63.9
mean wind v. m/s		1.2	2.5	3.9

rain fall (2.5 mm) was observed at the meteorological station the day before this survey
*; comparison with the air temp. under the green canopy in the park
run 8 23. Aug. 1992 12:30 - 13:40 JST fine

5. DISCUSSION

The thermal effects of large green canopy as "Cool Spot " were quite significant. From the result of comparing with built-up area and urban park (run 3 - 6), $\Delta T_{g\text{-}u}$ was especially significant in the early morning . The main reason of this phenomenon was a stability of air flow in the early morning.

But still in daytime, air temperature in large green canopy was cooler than urban built-up area about 1 °C. From the results of measurements in smaller green canopy, this tendency was also recognized. But in run 7, measured in promenade in daytime, one point in the street was cooler than in the green canopy. This reason is considered as followings; the condition that the space covered by green canopy in the promenade was designed to open widely to a heavy-traffic street, and the depth of the green canopy (about 10 - 30 meter) was too small to keep cooled air under the canopy in active air flow in daytime. Still in this case, surface temperature in the green canopy on the promenade was cooler than other points. From the results of measurement in and around a large urban park (run 1, 2), a distribution of air temperature and the effect of green canopy as "Cool Spot" was confirmed. But the thermal boundary area between "Cool Spot" and urban built-up area was not recognized from the survey. To discuss about this thermal boundary area, further investigation is needed.

6. CONCLUSION

In order to propose a green area as a unit of an urban environmental planning, measurements of meteorological elements were carried out in green areas and urban built-up areas in Osaka in August 1992. And the following results were obtained.

(1) The thermal effects of large green canopy as "Cool Spot" were quite significant.

(2) The thermal effects of green canopy was more significant in the early morning than daytime.

(3) The surface temperature was always cooler under green canopy.

(4) The tendency that the wind velocity under the green canopy was lower than other measuring points was recognized.

ACKNOWLEDGMENTS

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A SIMPLE PREDICTION MODEL OF AIR TEMPERATURE ON THE INSIDE OF STREET CANYON AND GREEN CANOPY

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ABSTRACT

It is tried to develop a simple prediction model of air temperature. Through this model, urban planers or architectural designers can easily understand thermal environmental problems. This model is a steady state calculation based on a heat budget of ground surfaces and imaginary spaces.
In this model, the air flow is expressed by the ventilation rate. Although the ventilation rate is not easy to determine, its concept is simple and very useful. Finally, the characteristics of the two extremes in a city, a street canyon and a green canopy, is examined by the calculation studies.

1. INTRODUCTION

It is very important to control the thermal environment not only inside of a building, but also outside space in a city, especially under the strict climate like the hot and humid summer in south-west Japan. It is well known that the green canopy have a wonderful effect to control the urban climate such as making a cool spot in a densely populated part of a city. A street canyon and a green canopy are normally the two extremes for the thermal environment in a city. It is significant to know the formation process of the thermal environment in these places of the two extremes. Because a kind of street canyon is expected to appear the maximum temperature in a city and a kind of green canopy is expected to appear the minimum temperature in a city.
In this study, it is tried to develop a simple prediction model of air temperature that urban planers or architectural designers can easily understand this subject. This model is a steady state calculation based on a heat budget of ground surfaces and imaginary spaces. And it is possible to link this model to one dimensional heat balance model.
In this model, the air flow is expressed by the concept of ventilation rate. Although the ventilation rate is not easy to determine, the concept of ventilation rate is simple and very useful. It seems easy to understand for planners and designers.

2. MODEL DESCRIPTION

2-1 STREET CANYON MODEL

The street canyon model is shown in Fig. 1. The main assumption of this model is as follows;
(1) The ventilation rate V_{CL2} between layer C and layer L2 is determined according to Nicholson1) and Mills2). Depth of layer L is defined by a coincident wind velocity above the roof and above the street canyon.
(2) The roof temperature is given by following equation.

$$\theta_{RF}=\theta_0+\Delta\theta_{L1}+(aI-L) / \alpha_t$$

θ_0: reference temperature
$\Delta\theta_{L1}$: temperature difference with reference temperature in layer L1
I: solar radiation, a: absorptivity of solar radiation , L: long wave radiation,
α_t: total convective heat transfer
When the surface temperature is given, the heat budget of the imaginary spaces in and above the street canyon is expressed for the imaginary spaces L1, L2, L3, C (see Fig.1). Although the surface temperatures of the inside of street canyon are given in this paper, it will be possible that it is given by the unsteady state calculation.
Finally, the equations are simply expressed as follows.

$$\begin{matrix} X_{11} & 0 & 0 & 0 \\ X_{21} & 0 & 0 & 0 \\ 0 & X_{32} & X_{33} & 0 \\ 0 & X_{42} & 0 & X_{44} \end{matrix} \quad \begin{matrix} \Delta\theta_{L1} \\ \Delta\theta_{L2} \\ \Delta\theta_{C} \\ \Delta\theta_{L3} \end{matrix} \quad = \quad \begin{matrix} C_1 \\ C_2 \\ C_3 \\ C_4 \end{matrix}$$

2-2 GREEN CANOPY MODEL

The green canopy model is shown in Fig. 2. The main assumption of this model is as follows.
(1) Heat and moisture transfer through the green canopy layers depend on only the air flow.
(2) The air flow is expressed by the ventilation rate.
(3) On the radiation exchange, the solar radiation is considered only the primary absorption. The long wave radiation is expressed only the outgoing radiation from leaves and ground surfaces to the sky.
(4) Ventilation rate of air layers, sky factor, convective heat transfer coefficients, these factors are given by exponential function as the attenuation curve from top of the canopy.
Equations of green canopy model is consisted of next 5 parts.
(1) Radiation balance (absorption of solar radiation and long wave radiation)
(2) Heat budget of green canopy air layer
(3) Moisture budget of green canopy air layer
(4) Heat budget of leaf surface
(5) Heat budget of ground surface
The unknown values are air temperature, leaf surface temperature, humidity ratio in each layer of green canopy. In this paper, the canopy layer is divided to 3 parts as shown in Fig. 2. In this case, the unknown values are 12.

3. COMPARISON WITH FIELD STUDY OF URBAN CANYON

3-1 OUTLINE OF FIELD STUDY

(1) Observation Place
Four streets in Nanba area of Osaka City, Japan. Two streets are situated north-south direction and the other two streets are situated east-west direction. This area is very crowded and most active place in Osaka City.

(2) Observation Date and Time
Total 25 observations during Aug. 1 to Aug. 6. 1992. The measuring time and weather are shown in Fig. 3.

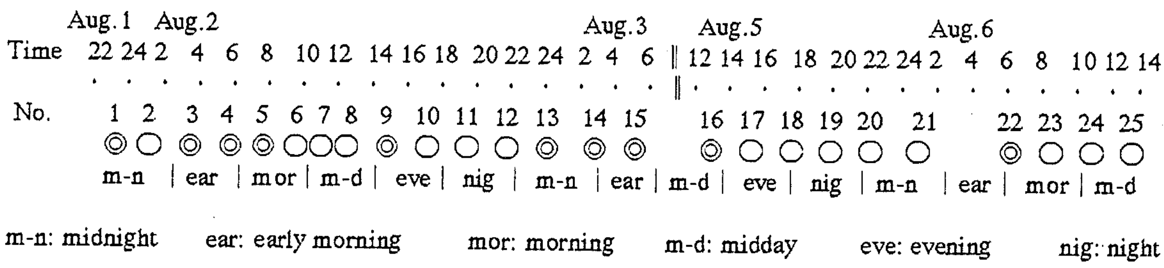

Fig.3 Measuring Time and Weather

(3) Elements of Observation

- air temperature (1.0m above the ground)
- surface temperature of walls and roads
- wind speed (1.0m above the ground)
- traffic counts of automobiles

3-2 RESULTS OF FIELD STUDY

(1) The air temperature in street canyon is always 1-2 °C higher than the Osaka Meteorological Station about 2 km away from the observation place.
(2) The road surface temperature is about 3 °C higher than air temperature even in the morning.
(3) The wall surface temperature is about 1 °C higher than air temperature in the morning.
(4) Surface temperature of the east-west direction roads is higher than the north-south direction roads, remarkably in night time.

3-3 RESULTS OF COMPARISON WITH FIELD STUDY

The result of the north-south direction street case is shown in Fig.4. From the night to early morning, the air temperature of street canyon is higher than the Meteorological Station. This tendency is coincident with the field observation.
In the daytime, calculation values are higher than observation values. This result seems because of the cool air by air-conditioning units coming from surrounding buildings.

4. CALCULATION STUDY OF GREEN CANOPY

4-1 CALCULATION CONDITIONS

In this calculation study, the assumption of meteorological conditions is based on the observed values on 21 August 1992 in Osaka (Table 1).

Tab. 1 Meteorological Conditions

	air temperature above the canopy	humidity ratio above the canopy	solar radiation
early morning	24.5 °C	0.015kg/kg'	0 kcal/m²h
midday	31.5	0.016	584

Leaf area density is 1 m^2/m^2 and the underground temperature assumed 25 °C based on the result of the observation.

4-2 RESULTS OF CALCULATION IN A GREEN CANOPY

(1) Effects on ventilation rate in early morning (Fig.5)
As the ventilation rate increases, leaf surface temperature arise. And also as the ventilation rate increases, air temperature arise. On the whole, as the ventilation rate increases, temperature differences of profile become small. However, as the values of the ventilation rate, more reliable values should be given by experiments or calculation.
(2) Effects on leaf area density in early morning
In this model, effects of leaf area density is tried to express the sky factor. As the sky factor increase, the leaf surface and the air temperature in the canopy layer become lower.
(3) Effects on evaporative ratio of leaf in midday
As the evaporative ratio increases, leaf temperature decreases. And as the evaporative ratio increases, the air temperature decreases.
(4) Effects on convective heat transfer coefficients in midday
As the convective heat transfer coefficients decreases, the leaf surface and the air temperature in the canopy layer become higher.

5. CONCLUSIONS

(1) The model of this paper is simplified, however it is expressed a essential points of its characteristics.
(2) Air flow is expressed by the concept of ventilation rate. It seems easy to understand for planners and designers.
(3) Using this model, the maximum and minimum temperature are able to evaluate in a city.
(4) In the next step, results of integrated experiments will be used for confirming the validity and usefulness of this model.

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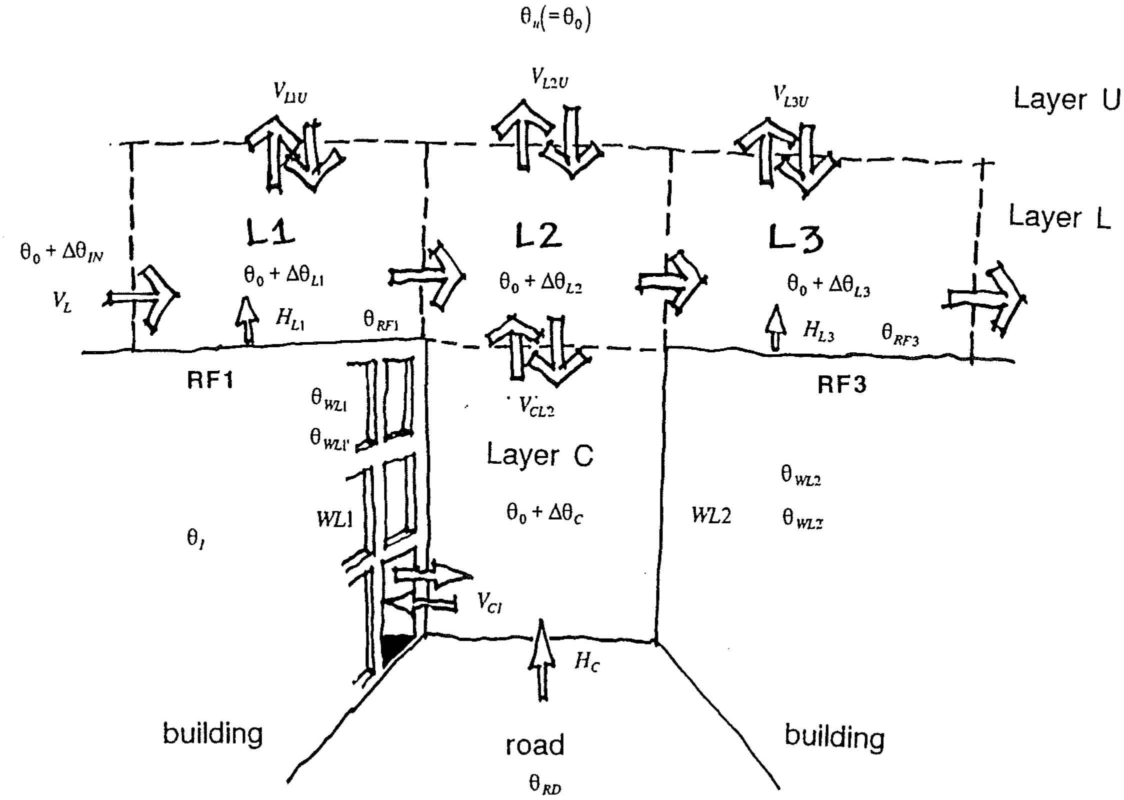

Fig. 1 Heat Budget Model of Urban Canyon

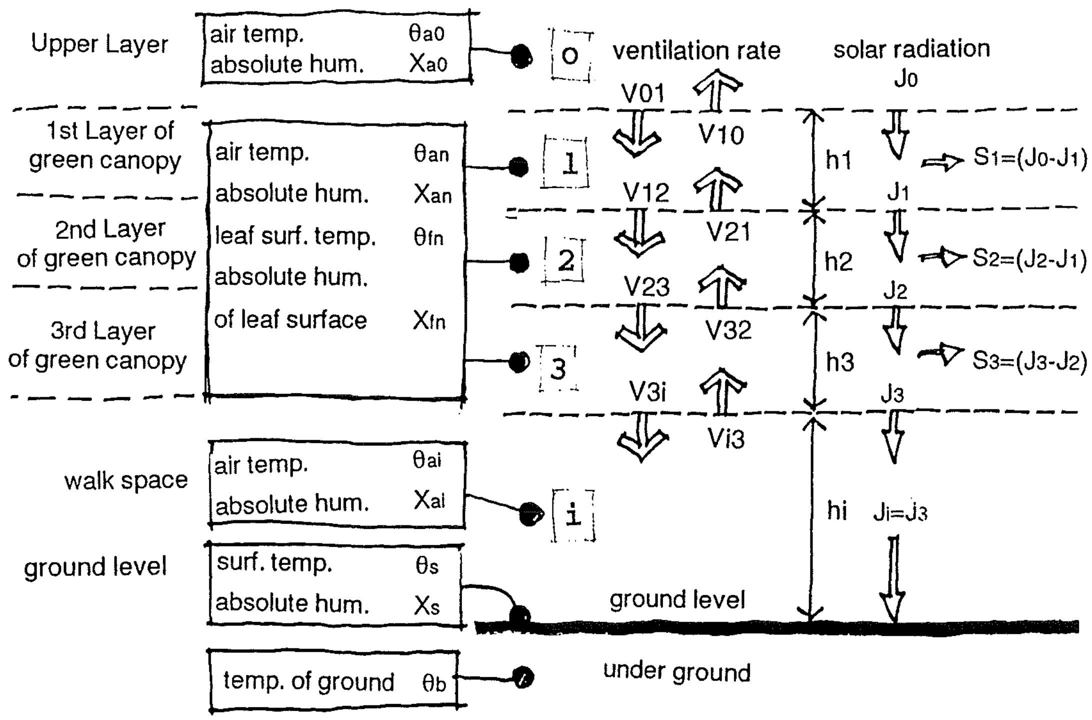

Fig. 2 Heat Budget Model of Green Canopy

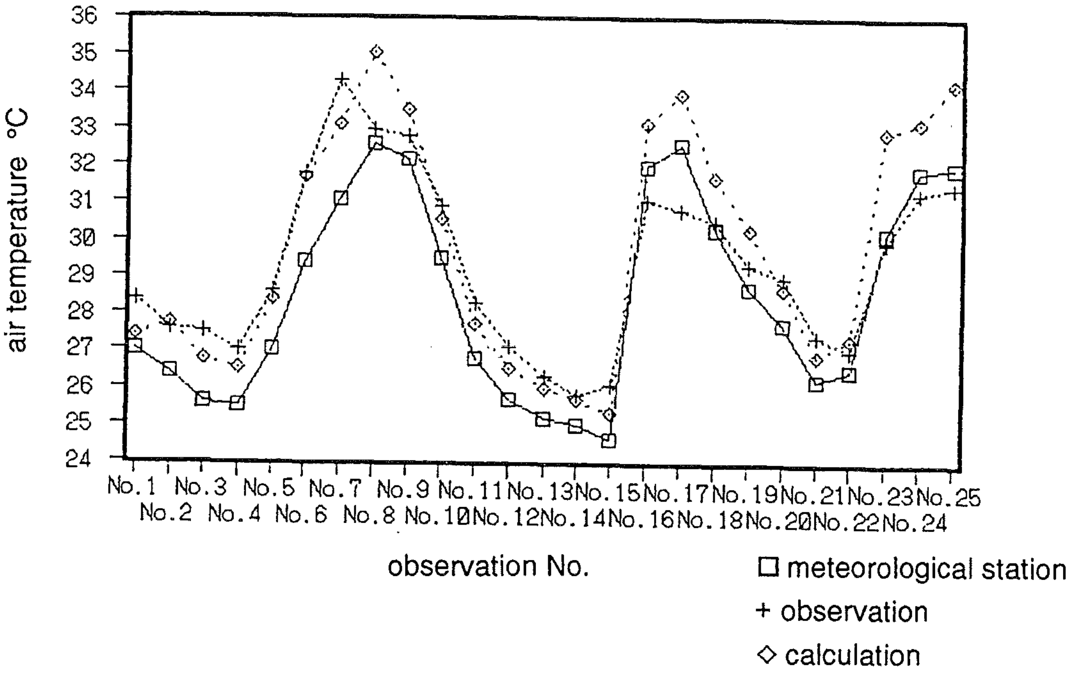

Fig. 4 Comparison with Field Study of Urban Canyon (in Case of North-South direction Street)

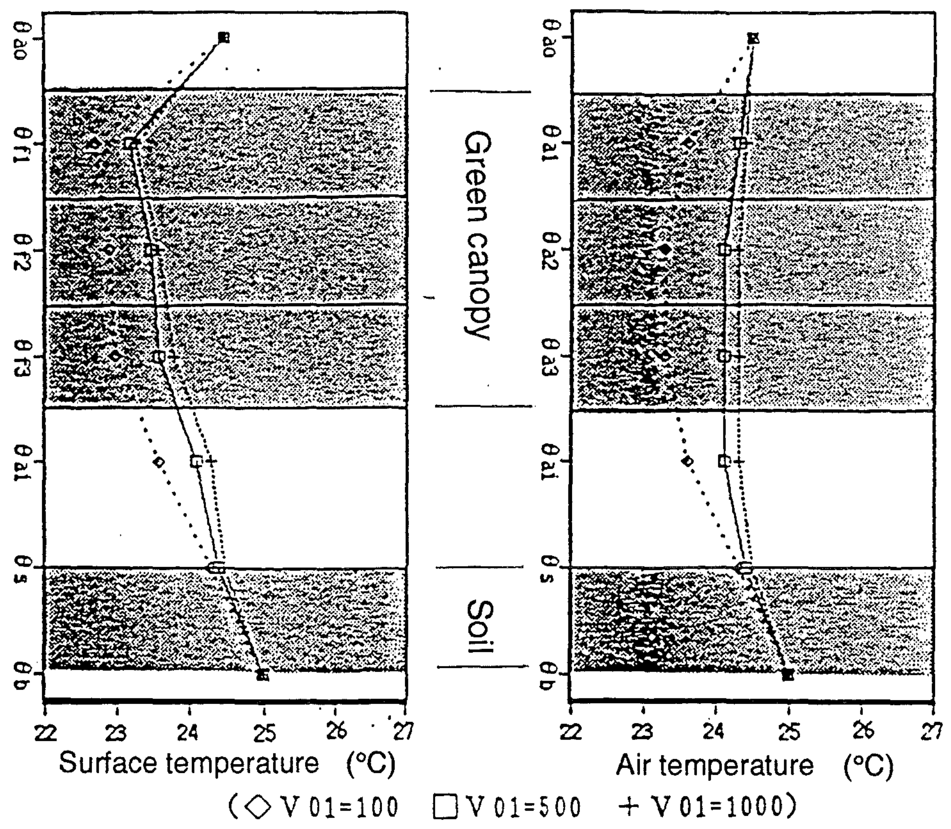

Fig. 5 Effects on Ventilation Rate in Early Morning

CITY PLANNING AND URBAN CLIMATE
– THE EXAMPLE OF KAMIOHOKA, YOKOHAMA CITY –

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ABSTRACT

In Japan, urban environmental planning projects have been started by ministry of construction. The purpose of this projects is mitigating environmental impacts of a city, urban heat island, energy consumption and so on. Almost Japanese cities have had a problem of thermal pollution in summer, so it's necessary that this problem will be solved quickly by re-composing an urban structure. Concretely, re-examining a site planning of buildings and green spaces, as the result of this, "wind way" in an urban area will be formed, and will contribute to ventilation and mitigation of an urban heat island.

This paper describes a climatic approach to city planning of Kamiohoka area. In this area, redevelopment plan has been progressed, so local government was driven by necessity to investigate it from the view point of an urban climate. Kamiohoka area situates at the valley, so main concept is maintenance of "wind way" parallel to the valley, therefore buildings are built not to screen from wind. Around this district, green area and garden trees are preserved and cultivated.

1. INTRODUCTION

In Japan, urban environmental planning projects have been started by ministry of construction since 1993. These were mostly worked by local governments, and subsidies were delivered to them by ministry. Its purpose is mitigating environmental impacts of a city, for example urban heat island, energy consumption and so on. Almost Japanese cities have had a problem of thermal pollution in summer, so it's necessary that this problem will be solved quickly by re-composing an urban structure. Concretely, re-examining a site planning of buildings and green spaces, as the result of this, "wind way" in an urban area will be formed, and will contribute to ventilation and mitigation of an urban heat island. In this paper, plan of Kamiohoka is introduced, case studies of recomposing an urban structure. Figure 1 is the geographical condition of Kamiohoka area where is situated between two hills.

2. BASIC CITY PLANNING

Former city planning is merely based on urban redevelopment as the sub-central area: accumulation of business and commercial area and culture center. On the other hand, this area has held the important problem. According to urbanization, residential area sprawled to suburban area, so green and open spaces decreased. Especially on the slope of both of the hills, residential area is sprawling toward the top of the hills. In other words, this situation is "either-or" orientation: on the one side, as the sub-central area, it must be promote accumulation of business and commercial area, on the other side, it must be control the sprawl of residential area and conservation of green and open spaces. Figure 2 is the former city planning items of Kamiohoka, for example, reconstruction of rail way station and traffic regulation, magnification of road width and so on. These plans are not considered an environmental conservation. Naturally characteristics of geographical and climatic situation are not made good to city planning, so this redevelopment is necessary to reexamine based on climatology.

3. CITY PLANNING AND URBAN CLIMATE

Figure 3 is anticipated climatic characteristics of this area. This district is situated on the river, Ohoka-gawa river, and at valley. So main concept of this redevelopment is maintenance of "wind way" parallel to the river and street, therefore buildings are built not to screen from wind. Concurrently "wind way" from the hills to this redevelopment area is also important. Figure 4 points out the problems of this area, decrease of green on the slope, insufficiency of urban facilities and so on. Figure 5 is planning idea of this area, present situation and plan. In this plan, accumulation as the sub-central area and climatic suggestions are described. The central area is high densely business and commercial area. Also traffic regulation is solved by separation of men and cars by pedestrian deck. Concurrently this deck is effective for "wind way" between the hills. Then on the slope of the hills, green area and garden trees must be preserved and cultivated.

4. PROBLEMS

While the discussion with public officers, there are some obstacles. First, as the scientist or engineer, obligation of scientific support caused very difficulties for want of enough meteorological data. In this area there is only one observatory, so especially expectation of "wind way" must be depended upon ordinary knowledge, in this case for example valley wind.

Moreover, there was a doubt that public officers recognized it indeed. They could realize this idea, urban environmental planning and "wind way", but couldn't realize that what was "wind way" or how "wind way" effects evaluated. It was caused by the first experiment about this project for most of Japanese. Also comparing with the cases by German and Japanese, it's seemed that difference of thinking is caused by the difference of climate and growth of vegetation. In Japan, at least in Yokohama, climate is warm and vegetation grows strongly, even if it's in an urban area. Vegetation is never dead, even if it's always well kept. Originally urban planning in Japan was complete equipment of urban facilities, but a program of environmental preservation would be a present purpose of city planning.

5. CONCLUSION

This paper described the case study of urban environmental planning in Kamiohoka. As compared with the former city planning, at the present, it became to be known better that a necessity of environmental preservation is recognized. There is a obligation of scientific support, enough meteorological data. In the future, it'll be indispensable to observe meteorological situation enough and to estimate the plan by wind tunnel experiment or field observation. It's hoped that this information is well utilized by also planners and designers.

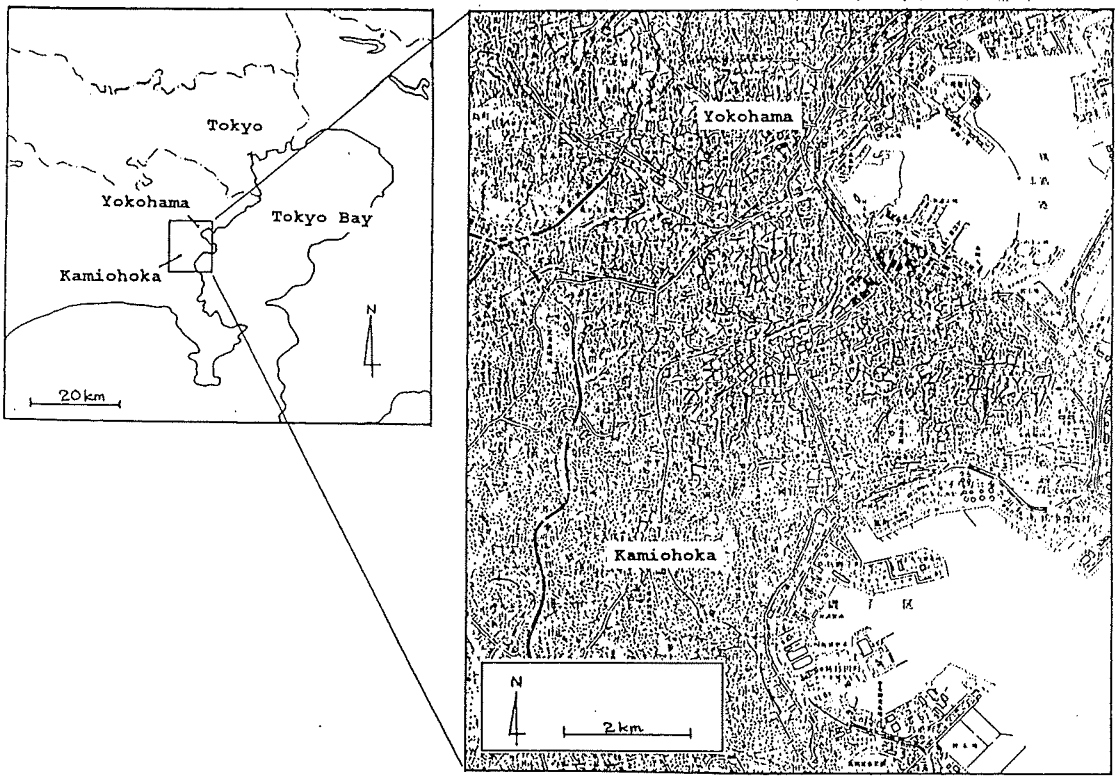

Figure 1 geographic situation of Kamiohoka

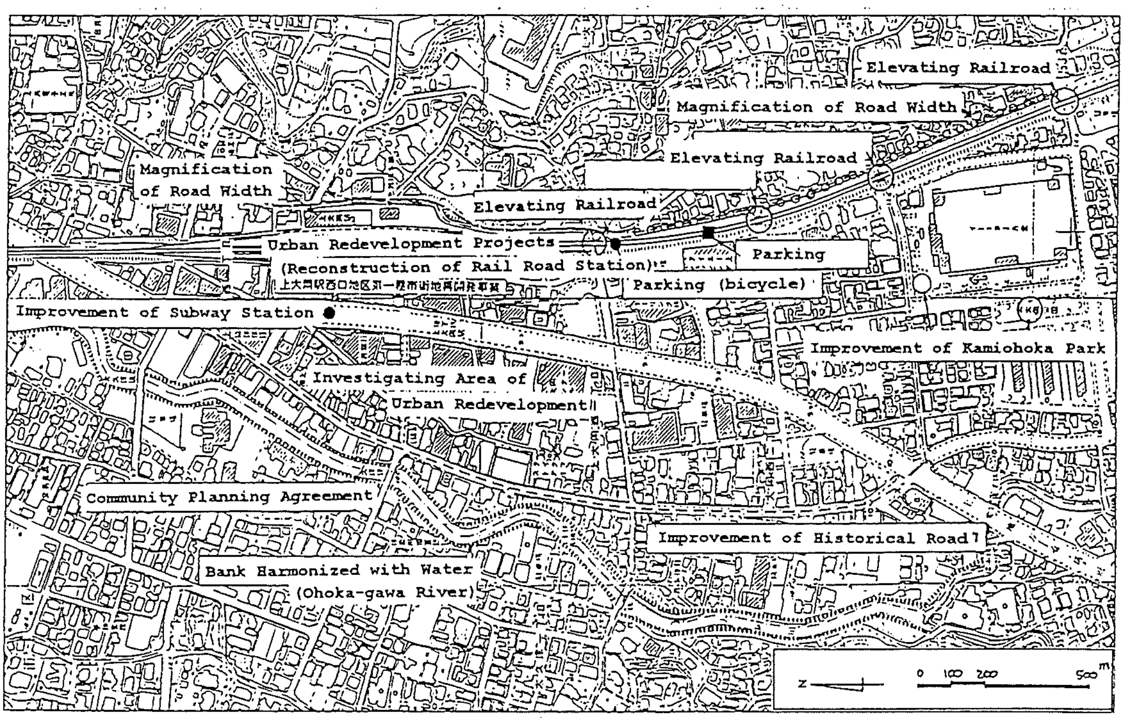

Figure 2 basic city planning items

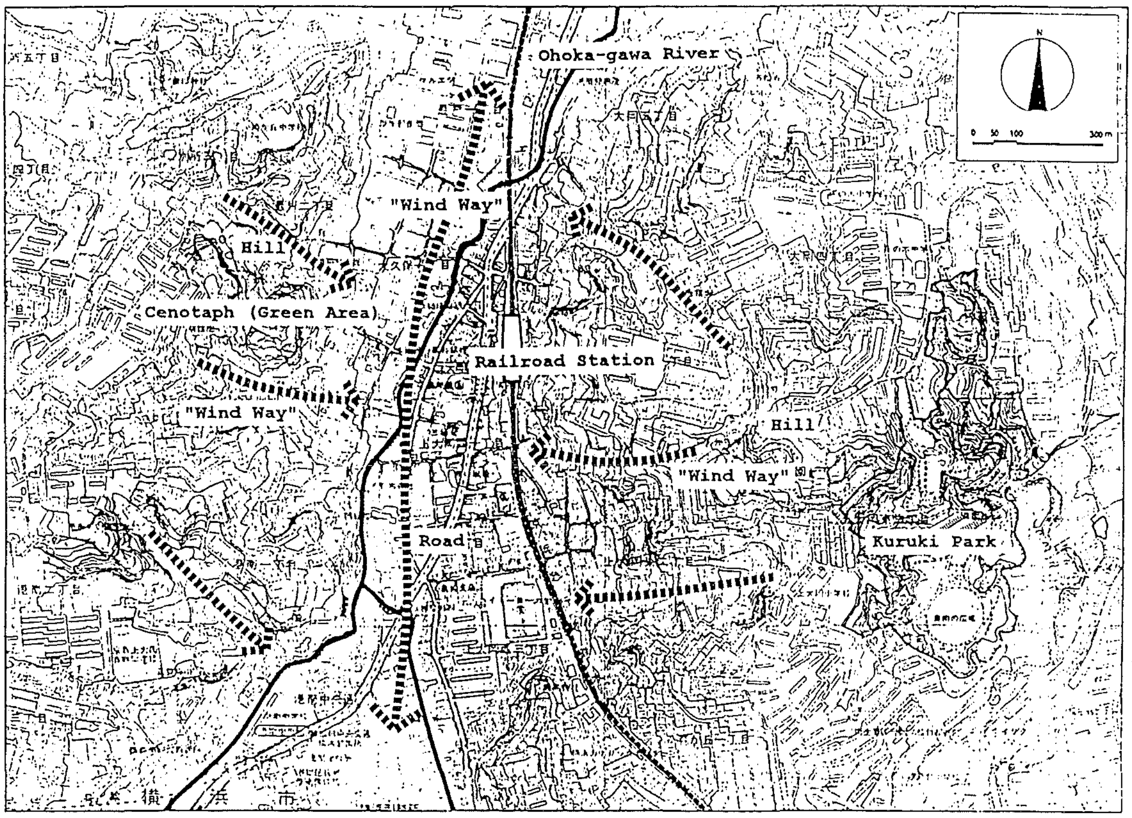

Figure 3 climatic characteristics of this area

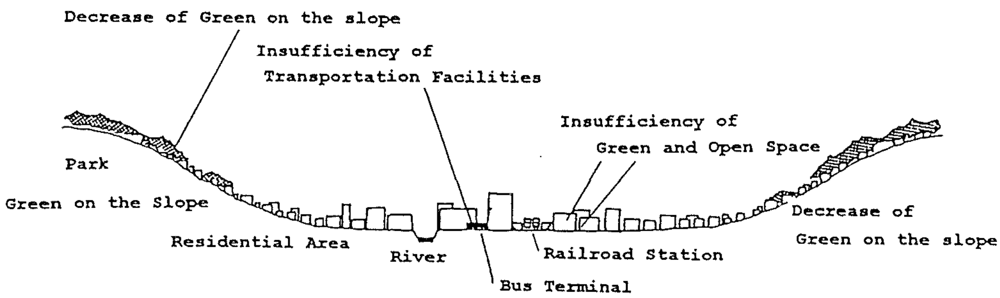

Figure 4 problems of this area

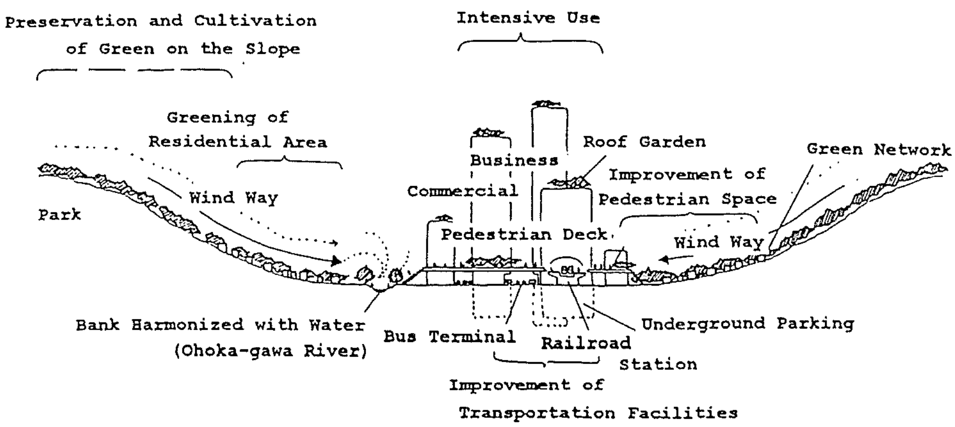

Figure 5 planning concept

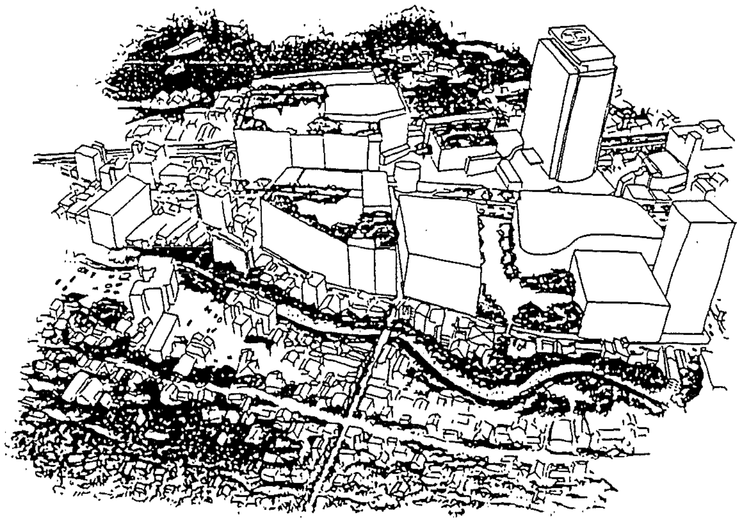

Figure 6 site plan (perspective)

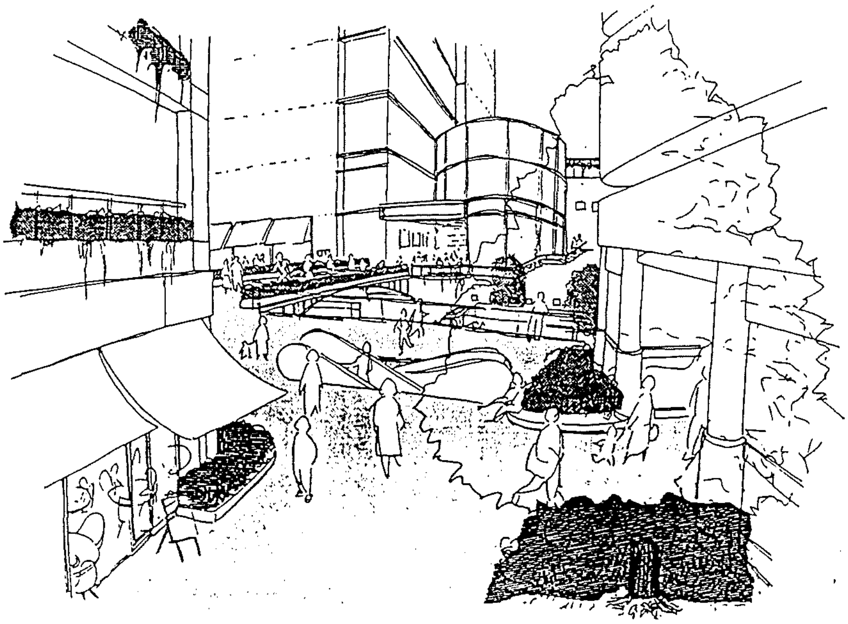

Figure 7 pedestrian space (perspective)

PRELIMINARY CLIMATIC STUDY OF THE KARLSRUHE AREA: PART 1 – UBIKLIM, A TOOL FOR CLIMATOLOGICALLY-RELATED PLANNING IN URBAN ENVIRONMENT

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ABSTRACT

Upon the request of the municipality of Karlsruhe a comprehensive study of the development in urban areas, titled "Belastungsgrenzen im Raum Karlsruhe", is being made. One part of this study covers at the climate, priorities being on the one hand on wind and drainage flow, on the other hand on the bioclimate. This contribution deals with investigations of the bioclimate.

Urban climate represents an expressive example of a man-made climate change that is susceptible, and therefore has to be considered early on in urban planning. The object of urban development is maintaining or even improving the climatic conditions directed to a healthy environment. In particular questions are of interest like: "What kind of urban structures tend to be bioclimatologically stressful? Which districts are appropriate for new development? etc".

The model UBIKLIM (Urbanes Bioklima-Modell) has been developed to provide answers to those questions. It enables a bioclimatological assessment of climate information. In the first instance UBIKLIM determines the meteorological fields of air temperature, humidity, wind velocity, and short- and long-wave radiation fluxes in the urban canopy layer on a summer day with fair weather conditions. Proceeding on the assumption that in a given climatic region the local atmospheric conditions are set by the climatic factors (these are land use, esp. urban structure – characterized by pavement, building height, building density, etc. – interactions between adjacent structures, and topography), knowledge of a DHM (digital height model) and appropriate land use information allows to calculate the meteorological fields. These meteorological parameters determine the heat exchange conditions of the human being and thus can be analyzed with the help of the Klima-Michel-model in physiologically significant terms.

The result is a bioclimate map on a scale that is appropriate for climate-related planning in urban environment. In addition to the description of the present situation UBIKLIM also makes it feasible to assess the impact of changes of land use or urban structure on bioclimate.

1. INTRODUCTION

With regard to a forward-looking regional and urban planning communities increasingly order comprehensive studies of settlement potentialities within their territory. Thereby investigations of a multitude of subjects are being made, for example of traffic, air pollution, climate, etc.. In this context such a study of the development in urban areas, titled "Belastungsgrenzen im Raum Karlsruhe" is being made upon the request of the municipality of Karlsruhe. One part of this study covers the climate, priorities being on the one hand wind and drainage flow, on the other hand the bioclimate. This contribution deals with investigations of the bioclimate.

Though urban climate represents an expressive example of a man-made climate change that is susceptible, and therefore has to be considered early on in urban planning, the available fundamentals and methods of inquiry often suffer from being too abstract. A consideration of the impact of the atmospheric conditions on the human being, the so-called biometeorological assessment, leads to statements that are relevant for planning.

With regard to a healthy living space the following questions are of special interest in urban planning:

- What kind of urban structure tends to be bioclimatologically stressful?
- How can development plans be optimized?
- What arguments can be deduced for laying down development regulations?
- Which districts are appropriate for a new development?
- Which areas are given priority?

The Deutscher Wetterdienst has developed the model UBIKLIM (Urbanes Bioklima Modell) to provide answeres to these questions.

2. UBIKLIM

The human being is most closely linked with the atmospheric environment by the heat regulation. In this connection air temperature, humidity, wind velocity as well as short and long wave radiation are the important atmospheric elements. Consequently, as a first step, UBIKLIM calculates the fields of these parameters which determine the heat exchange conditions of the human being and thus can be analyzed with the help of the Klima-Michel Model in physiologically significant terms. In order to gain comparable statements clothing and activity have been fixed.

The result is a bioclimate map of a scale of 1:25 000, resp. 1:10 000, appropriate for climate-related planning in urban environment. The map shows the spatial distribution of heat load intensities, expressed by steps of PMV (predicted mean vote).

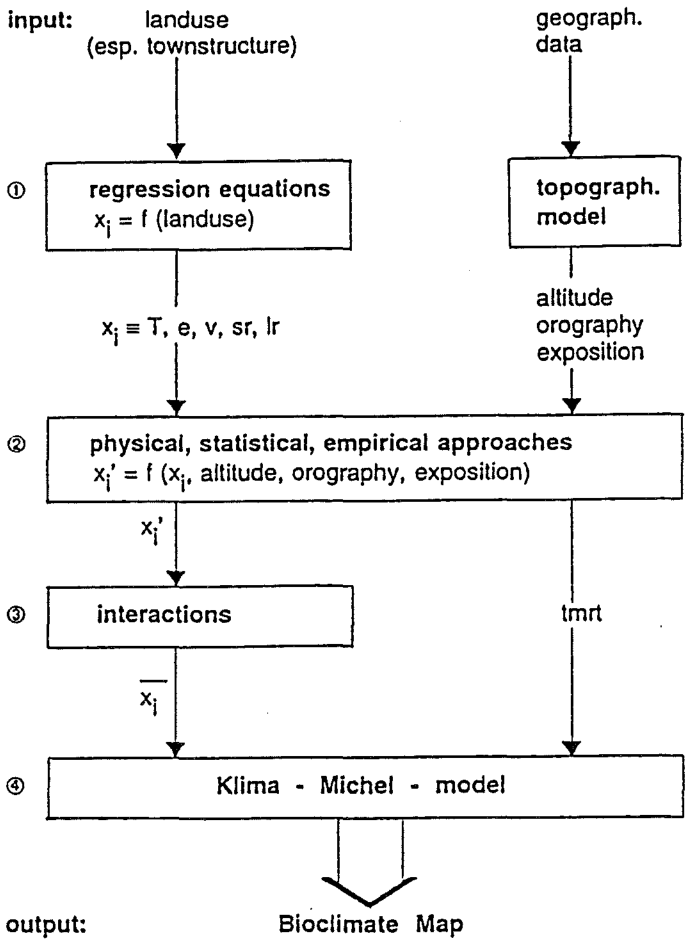


Figure 1.

The stucture of UBIKLIM

3. INPUT DATA

Proceeding on the assumption that in a given climatic region the local atmospheric conditions are set by the climatic factors, knowledge of a digital height model (DHM) and appropriate land use information allows to calculate the meteorological fields.

While digital height data can be prepared routinely, the supply of land use data, especially data of urban structure is more problematic. As it seems not to be necessary to enter into the last detail, it will do to divide the entire investigation area into a limited number of districts, each one of them characterized by its own land use type. The main types are water, forest, meadow, field, paved open space, street, residential area, industrial area. According to certain development parameters (pavement, building height, building density, etc.) the built-up area is further divided. On the basis of these data corresponding to figure 1, the meteorological fields can be calculated in several steps. Finally the bioclimatological assessment can be made at each point of the investigation area.

4. APPLICATIONS

"Am Hagenberg", Allstedt (Figure 2)

For developoment purposes the district "Am Hagenberg" of the town Allstedt was to be taken out of the *Area of Outstanding Natural Beauty* "Unstrut Trias". Therefore investigations had to be made whether the planned development would cause climate changes with relevant consequences for planning or not. For the inquiry UBIKLIM has been used. Therefore an area of about 1 km^2 in the eastern part of Allstedt was subdivided into 35 sites with different land use types, inclusively different types of urban structures. With these data and the information about topography, a bioclimatological assessment of the existing urban situation has been realized.

It is less topography than the arrangement of the different land use types that forms the represented distribution. Especially where several smaller areas of different land use types are adjacent, interactions between these areas entail distinct modifications. Here interaction means a compensation flow with horizontal advection from cold to warm areas, where the warm air is forced to ascend and is substituted by colder one. At the maximum after 100 meters the influence of the adjacent site wears off.

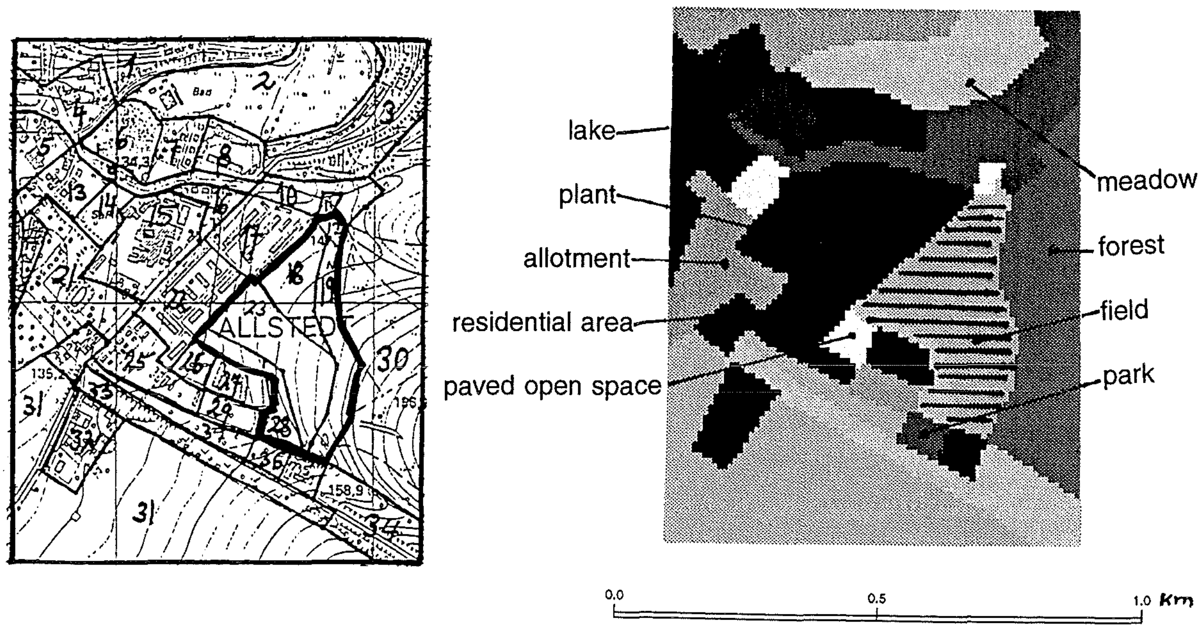
In the forest – at the eastern edge of Allstedt – and in the nearest region of the lake, the PMV-values are lowest. In contrast to this the thermal situation within the built-up areas is most stressful. In particular the completely paved area of the plant in connection with the adjacent residential area are problematic. According to the planning conception the development of the area "Am Hagenberg" enlarges this problematic zone and the possibility of thermal relief in the already existing residential area from the Hagenberg vanishs. To minimize the negative result the idea of a green belt of at least a 50 meters width between the existing and the planned development should be realized. A further reduction of the expected thermal stress can be obtained when the built-up areas are densely planted with trees.

The Karlsruhe Area (Figure 3)

In the course of the study titled "Belastungsgrenzen im Raum Karlsruhe" investigations of the bioclimate in the Karlsruhe area are being made. The first step is about an assessment of the current bioclimatological situation. The second step is forward-looking: With the updating of the land development plan new development areas shall be set, harmlessly to the climate. Before reviewing the draft of the land development plan, climate changes caused by the new development must be grasped and assessed, which might be of significance to the human-beings.

The data basis available is a DHM and detailed land use information (including more than 4000 areas with different urban structures or land use types), appropriate for the handling with UBIKLIM.

Input Data



Results

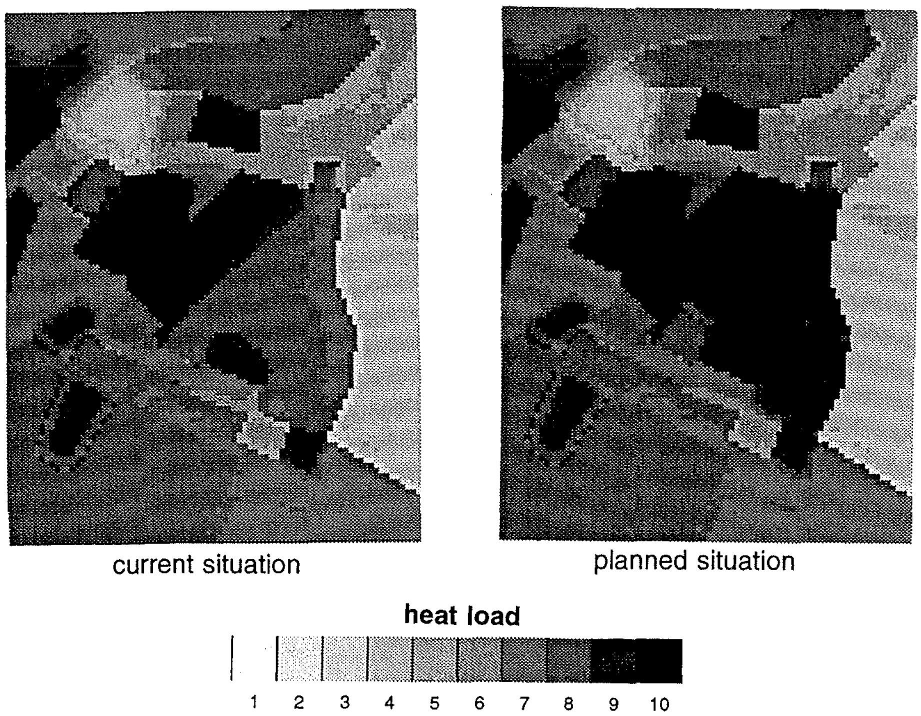
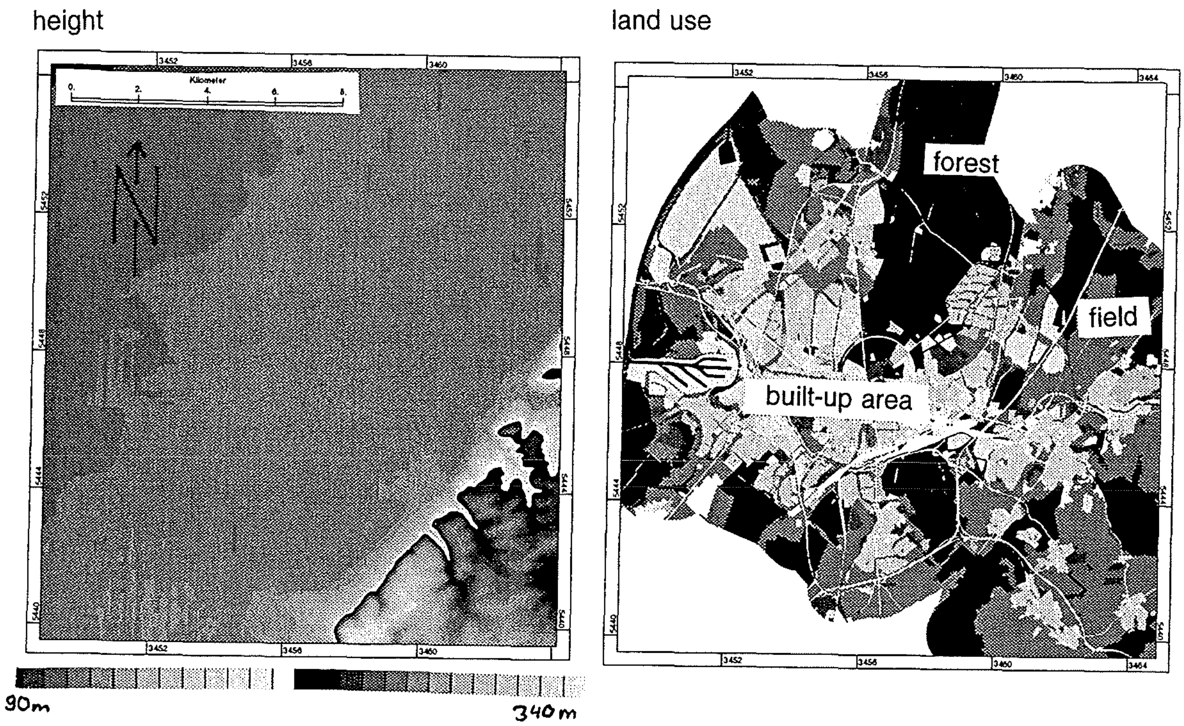


Figure 2. "Am Hagenberg", Allstedt



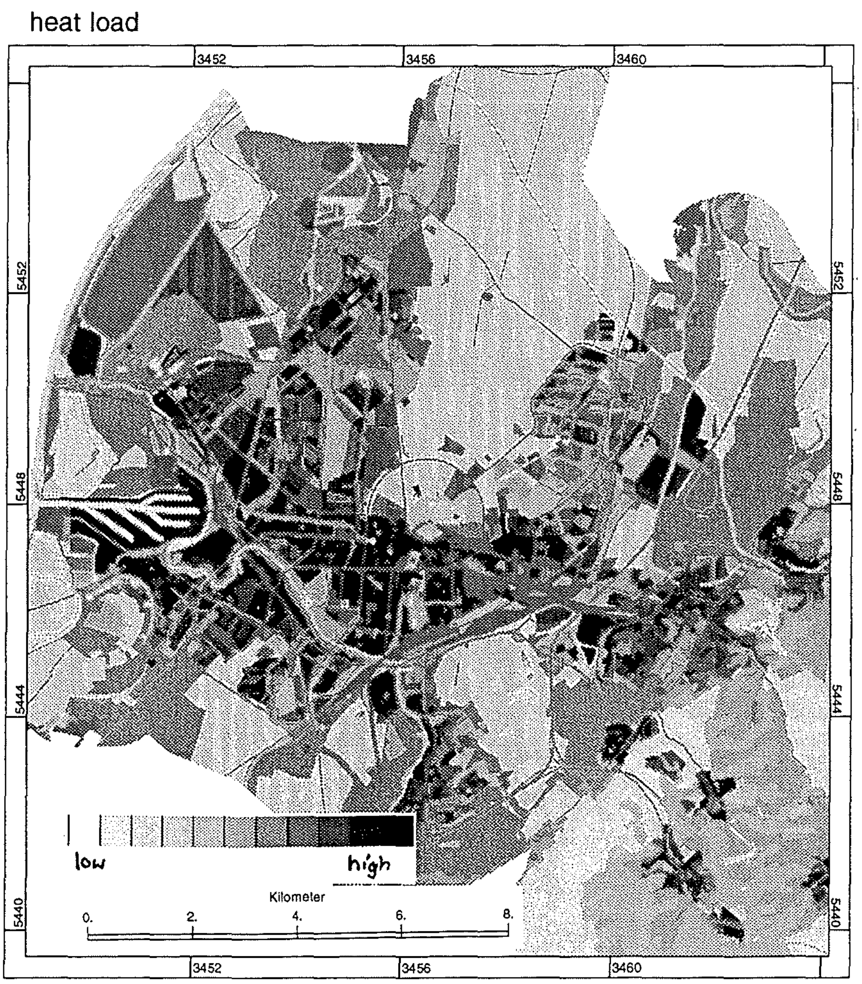


Figure 3
The Karlsruhe Area

A first provisional result is given in figure 3. It shows the current distribution of heat load of almost the entire Karlsruhe area. As the major part of the Karlsruhe territory is situated in the Rhine valley with only little differences in the topography, the bioclimatological situation is dominated by the kind and the arrangement of land use types, resp. urban structures. Only in the south east the rising height of the Northern Black Forest has an effect on bioclimate.

In Karlsruhe three land use types are mostly respresented: forest, open space, built-up area; they are clearly recognizable in the bioclimatic map. Particularly striking is the large forest area, which reaches with its low heat load values from the northern edge into the centre of the city. Apart from that smaller woods, fields and meadows with a medium level of heat load, characterize the situation of the outskirts. There the suburbs are rather lightly built up and additionally a good number of trees are planted. Even if the stress values are higher than over the fields or in the forest, on the whole they do not reach a problematic level. Besides, it is not very far to leave a stressful site.

In contrast to this the situation in the city is more delicate. Caused by dense development and massive pavement a solid complex of heat load has established, that spreads south of the castle over an area of about 6 km^2. Only a few parks break up this complex. From a bioclimatological point of view no further development should follow, and the planting of trees should be intensified.

5. FURTHER OUTLOOK

The represented investigations deliver plausible results at daytime in general and at night over a flat territory. In that case the occurrence of compensation flows, as considered in UBIKLIM, is probable. Otherwise drainage flows develop in a well structured topography. They may modify the bioclimate recognizably and consequently have to be considered.

In the south-east of the Karlsruhe area such flows are expected. Therefore cooperation with the "Ingenieurbüro Lohmeyer" is planned (contribution of Dr. G. Schädler). This consulting bureau will calculate the expected flows which at a later stage have to be incorporated into the bioclimatological assessment.

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PRELIMINARY CLIMATIC STUDY OF THE KARLSRUHE AREA: PART II - WIND FIELD AND DRAINAGE FLOWS

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ABSTRACT

The study forms part of a joint climatic analysis (together with Deutscher Wetterdienst) of the Karlsruhe area. Its objective is a quantitative description of the wind field near the ground in general and drainage flows in particular of the Karlsruhe area by means of numerical modelling. The results are intended to be used in urban development planning (housing, industrial sites, roads).

1. INTRODUCTION

With the project entitled "Belastungsgrenzen Raum Karlsruhe", the city administration of Karlsruhe has initiated a study to assess the climate and air quality in the city area. The study is coordinated by Prof. Höschele. It comprises three parts: Bioclimate, Wind/Drainage Flow and Air Pollution due to vehicle exhausts, industry and other sources. It investigates the present situation and a projected situation. In this contribution, we shall deal only with those aspects concerning wind. Of course there are close connections with the other two parts. The objective of the wind part is to provide high-resolution quantitative information about the wind field near the ground and about drainage flows for the whole city area.

2. STATE OF KNOWLEGDE

The general wind field and drainage flows in the Karlsruhe area have been described in a number of publications (e.g Höschele, 1980, Fiedler, 1983). This is due partly to the phenomenon of channeling which occurs in large valleys causing the wind in the lower layers of the atmosphere to follow the valley axis. This effect can be clearly seen in the wind roses of cities like Karlsruhe or Mannheim, for example. Channeling is most pronounced in the valley, but extends to the valley slopes as well. The city area of Karlsruhe extends from the Rhine river to the foothills of the Black Forest, covering a range of height of about 110 m to about 350 m. In the mountainous region to the east of the city, a number of valleys draining into the Rhine valley cause drainage flows which affect the eastern suburbs of Karlsruhe, such as Durlach and Grötzingen. However, these drainage flows only extend about 1 km into the valley and therefore do not reach the city centre which is about 10 km away. Those drainage flows are well documented in data from meteorological stations situated at the sides of the Rhine valley between Grötzingen and Durlach. They show up markedly in the wind statistics of those stations.

3. URBAN PLANNING - THE NEED FOR MORE INFORMATION

For the purposes of urban planning there is a need to extend on the knowledge which has been accumulated up to now. Especially the following points have to be elaborated on:

- how is the wind speed and wind direction affected by the different land uses within the city area (densely built-up areas, suburban areas, forests, open land) and the mountainous topography? That means that it is desirable to have wind statistics at arbitrary points of the city area which can be used for dispersion calculations and for the planning of building complexes, for example.
- where do drainage flows occur, what parts of the city do they affect, what is their volume flux and their thickness, how far do they extend into the Rhine valley, do they bring clean air or polluted air?

4. METHODS

In this study, the above mentioned questions are treated by means of numerical modelling. The models used are the diagnostic wind field model DIWIMO and the drainage flow model KALM, both developed at Ingenieurbüro Lohmeyer, Karlsruhe. The wind field model calculates a mass consistent wind field in a terrain following coordinate system, starting from a prescribed initial wind field. The drainage flow model calculates the time-dependent wind field and drainage flow thickness; together with validations, it is described in Schädler and Lohmeyer, 1994. As input, both models need digitised topography and land use. Output includes maps of wind fields, layer thickness and volume fluxes as well as wind statistics at arbitrary locations. Both models are routinely used in our company. In the present study, the meteorological measurements available are used to check the model results and to calibrate the models. For the present case, a nested version of the model KALM has been used.

Topography and land use data were provided by the "Institut für Geographie und Geoökologie der Universität Karlsruhe", meteorological data came from the "Institut für Meteorologie und Klimaforschung" and "Deutscher Wetterdienst".

5. RESULTS SO FAR

Drainage flows:

First, a larger scale (10 km x 10 km, resolution 200 m) survey calculation was performed (Fig. 1). In a second step, for selected areas with significant flows near Grötzingen and Durlach, higher resolution calculations (grid size 50 m) were performed with the nested model. These calculations gave an overview over the spatial distribution of the drainage flows and confirmed the known facts about the drainage flows in the area, namely that they extend about 1 000 m into the Rhine valley and that significant flows occur at Grötzingen, Durlach and between Durlach and Wolfartsweier. The results were processed as maps of wind field, thickness and volume flux at different scales.

Wind field:

For the wind field, survey calculations have been done so far. They show that the wind direction does not change much within the Rhine valley, only the wind speed varies there depending on the terrain roughness. At the sides of the valley, however, several single elevations modify wind speed and wind direction, so that wind statistics can be expected to differ from those in the Rhine valley.

Ingenieurbüro Lohmeyer

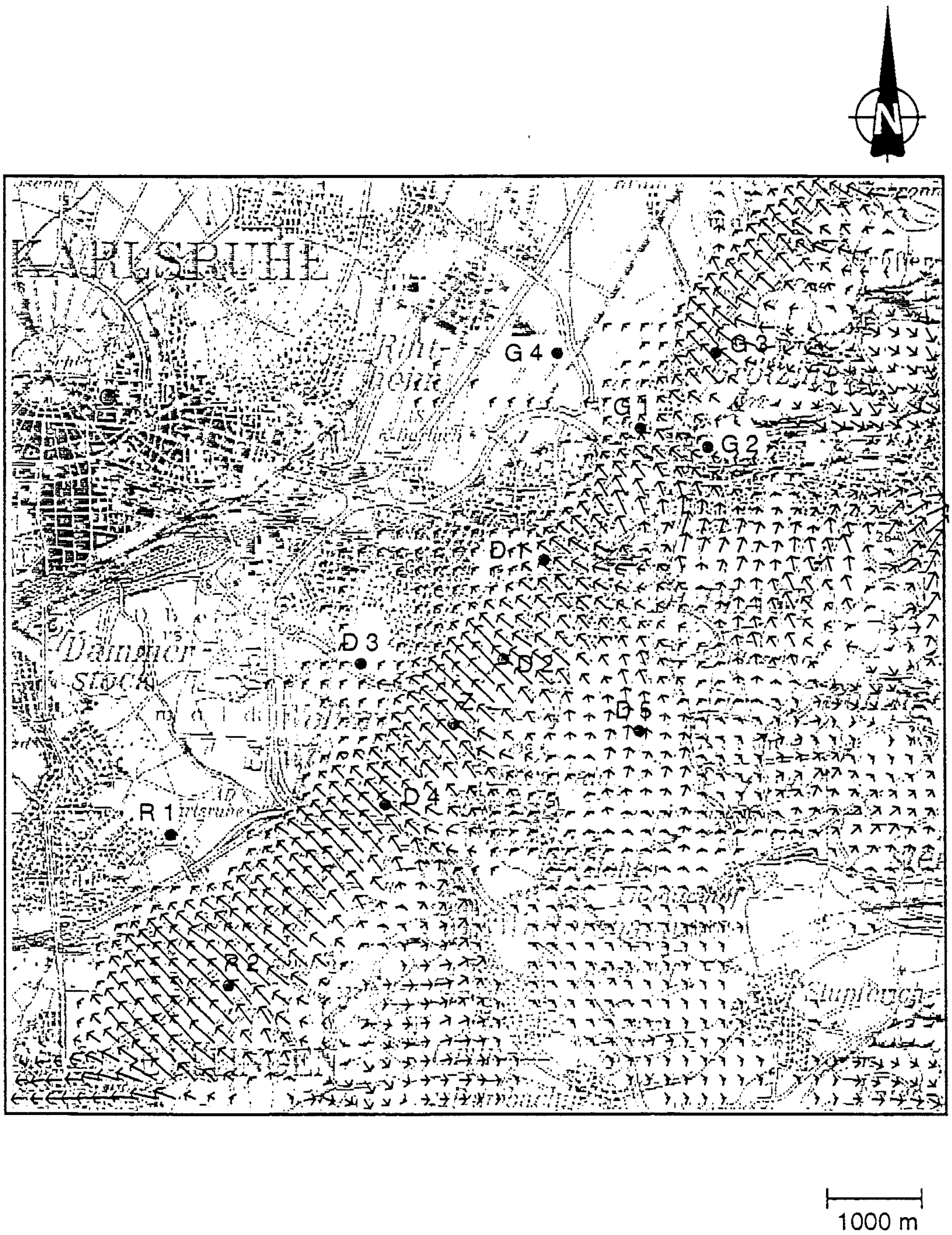

Fig. 1: Calculated drainage flow wind field. Observation sites are marked. Maximum vertically averaged speed is 1.8 m/s.

6. OUTLOOK

The next steps in the project are:

- identify climatically relevant flows in more detail
- check results against field data
- produce detailed maps of the drainage flow,
- calculate the wind field in higher resolution
- produce maps of the wind field
- calculate high resolution wind statistics
- discuss the relevance of the results in the context of urban planning

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