WORLD CLIMATE PROGRAMME

APPLICATIONS

BIBLIOGRAPHY OF URBAN CLIMATE

1981 - 1988

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WCAP - 15

WMO/TD-NO. 397

WORLD METEOROLOGICAL ORGANIZATION

(December, 1990)

The World Climate Programme launched by the World Meteorological Organization (WMO) includes four components:

- The World Climate Data Programme
- The World Climate Applications Programme
- The World Climate Impact Studies Programme
- The World Climate Research Programme

The World Climate Research Programme is jointly sponsored by the WMO and the International Council of Scientific Unions.

INTRODUCTION

This bibliography is a continuation of a series which provides a fairly complete summary of work in the field of urban climatology. The full sequence starts with the bibliography of Chandler (WMO Publication No. 276, 1970) which covers references from the beginning of the subject up to about 1968. This is followed by the two publications of Oke (WMO Technical Notes No. 134, 1974 and No. 169, 1979) which cover the periods 1968-73 and 1973-76 and include both a review and the corresponding full bibliographies, and most recently the bibliography of Oke for the period 1977-80 (WMO WCP-45, 1983). It should be noted, however, that all the publications mentioned above are now out of print.

The scope of urban climatology included in this bibliography extends upward from the scale of a single house to that of whole cities. It concerns both the impact of urban development upon all aspects of the atmosphere and the response of populations to the resulting climate. Because the possible fields involved are many it is also necessary to state what is specifically excluded. The bibliography does not include most work in such cognate fields as urban air pollution, urban hydrology, building climatology, wind or solar engineering unless the work has a special relevance to, or overlaps with, urban climatology itself.

Most of the literature listed herein is easily accessible in the sense that it is located in standard scientific journals or books. Items such as internal reports of institutes, and university or government research departments are not included unless the item is deemed of special interest and covers material not already reported in the open literature. The coverage is somewhat biased towards the English-speaking literature since the author depends on abstracting services and the goodwill of others to draw attention to work in other languages. Titles of non-English work have been translated into English but the language of the original is noted at the end of the citation in brackets. The completeness of the coverage tends to drop towards the end of the period. A few references prior to 1981 are included if they were omitted from earlier bibliographies in the sequence.

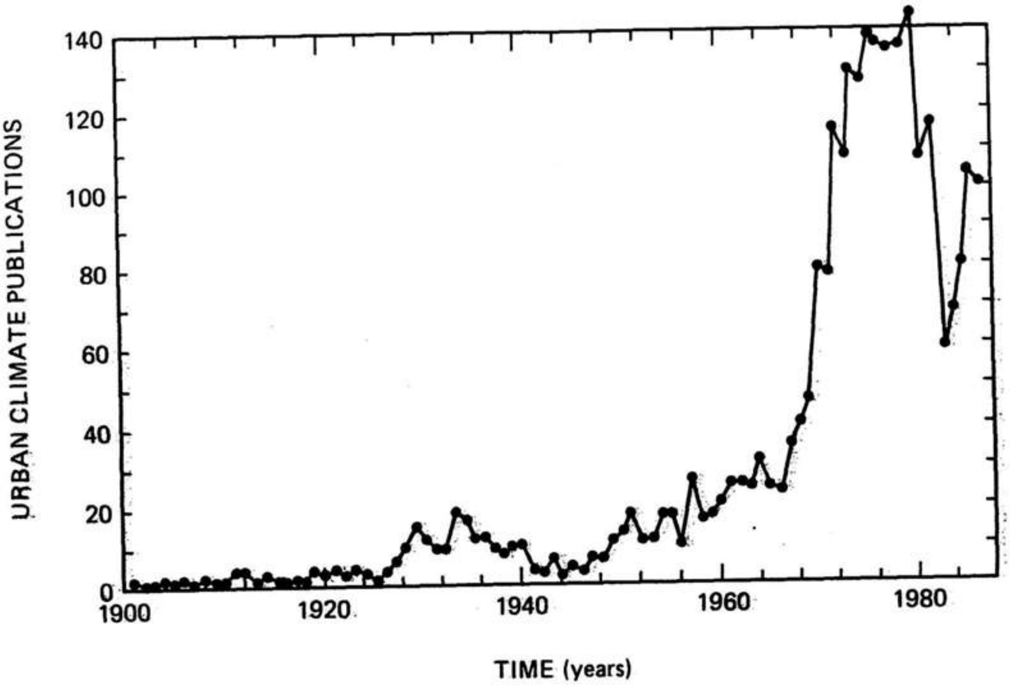

Figure 1. Annual totals of publications in urban climatology in the twentieth century.

HIGHLIGHTS FROM THE 1981-88 LITERATURE

A simple indication of the vigour of a subject is given by the number of publications appearing each year. This is graphed for urban climatology from the beginning of this century in Figure 1. It is constructed using the sequence of bibliographies published by WMO. The similar graph in the previous bibliography displayed what appeared to be a dismaying plummet in publications after a massive outpouring in the 1970's. It is perhaps too early to report with certainty but it seems possible that in fact the 1970's were an anomalous surge on an otherwise steady and nearly exponential growth which continues (i.e. if one draws a curve joining 1967 and 1983). It is also good to report that the field has just established the first journal devoted to urban climatology and meteorology (**Atmospheric Environment, Part B -Urban Atmosphere**).

During the period there were several important conferences entirely or mostly concerned with urban climate issues: IFHP on The Impact of Climate on Planning and Building in 1980 at Herzliya on Sea, Israel (Bitan, ed. 1982b); AMS/EPA on Modelling the Urban Boundary Layer in 1983 at Baltimore, MD (AMS 1987); IFHP/WMO on Applied Climatology and its Contribution to Building and Planning in 1983 at Tel Aviv, Israel (Bitan, ed. 1984); WMO/WHO on Urban Climatology and its Applications with Special Regard to Tropical Areas in

1984 at Mexico City, D.F. (Oke, ed. 1986); Chinese Assoc. Geographers on Urban Climate and Urban Planning in 1985 at Beijing and in 1987 at Guilin, P.R.C. (Chinese Assoc. Geog., 1985); Int. Symposium on Urban and Local Climatology in 1986 at Freiburg, F.R.G. (Anon. 1986); IFHP on Climate, Building and Housing in 1986 at Karlsruhe, F.R.G. (Bitan, ed. 1988); WMO/PAHO Conference on Urban Environment in 1987 at Sao Paulo, Brazil; Conference on Urban Meteorology in 1987 at Belgrade, Yugoslavia (Anon. 1987).

Four important new books in the field appeared in the period covered by this report. **The Urban Climate** by Landsberg (1981b) is a survey of the research literature in the subject, **The Urban Atmosphere** by Atkinson (1985) draws attention to recent advances in our physical understanding and **Introduction to Urban Climatology** by Chow (1985a) is a full text with special interest because of its inclusion of much of the Chinese literature. **Urbanization and the Atmospheric Environment in the Low Tropics** by Sham (1987a) combines a review of the field with the extensive work of the author in the Equatorial city of Kuala Lumpur.

Several comprehensive reviews of the field or special subjects within it were also published. These include the general overviews by Landsberg (1981a), Lee (1984) and Kuttler (1988) and the reviews of methods by Oke (1984a) and Taesler (1986); urban climate models by Bornstein (1986); tropical city climates by Jauregui (1986a) and Oke (1986b); urban topoclimatology by Goldreich (1984a); orographic influences on urban climate by Wanner (1989); urban heat islands by Oke (1982b); flow around buildings by Hosker (1985) and the urban energy balance by Oke (1988). There are important summaries and suggestions for the use of climate in urban design in the books by Thurow (1983) and Lowry (1988). Of special note also is the final summary volume of the METROMEX urban meteorology and precipitation modification project (Changnon, ed. 1981a).

Whilst it is difficult to assess what constitute advances in a field the following selection from the bibliography is offered to show what the author judges to be examples of work from the period which illustrate the way urban climatology is progressing towards better understanding.

Field observations of the flow in an urban canyon by DePaul and Shieh (1986) reveal the details of the characteristic rotor flow to be found in streets. Based on wind tunnel measurements by Hussain and Lee (1980) Hosker (1985) has been able to generalize the flow regimes found over reasonably uniform arrays of buildings. Very careful and almost complete measurements of the turbulent spectra and flux cospectra over urban sites have been reported by Clarke <u>et al.</u> (1982), Högström <u>et al</u>. (1982) and Roth (1988). At larger scales Bornstein and Thompson (1981), and Gaffen and Bornstein (1988) have demonstrated the ability of urban areas to have a significant influence on the passage of mesoscale and synoptic fronts, and Elsom and Meaden (1982) confirm the effect of large cities in suppressing tornadoes. Knowledge of the spatial and temporal behaviour of the urban boundary layer depth has been forwarded by the work of Godowitch <u>et al.</u> (1985,1987), Goldreich <u>et al.</u> (1981), Surridge and Goldreich (1988) and Uno <u>et al.</u> (1988). Boundary layer fluxes and other turbulent quantities have been measured using airborne sensors (Hildebrand and Ackerman, 1984 and Ching, 1985).

The surface radiation, energy and water balances of urban areas have been observed in several cities. Estournel <u>et al.</u> (1983) provide urban-rural comparisons of long- and short-wave radiation for Toulouse. In addition to confirming the attenuation of solar terms they show the 'greenhouse' of the urban atmosphere to prevail throughout the day and night. Spatially representative energy balances of urban terrain obtained from towers well above the building layer are now available (Kalanda <u>et al.</u> (1980), Ching <u>et al.</u> (1983), Oke and McCaughey 1983, Kerschgens 1987) and also urban-rural comparisons (Ching <u>et al.</u> 1983, Cleugh and Oke 1986). In general they confirm prior expectations except that the role of evaporation is often larger than predicted. This result based on energetic reasoning has also been confirmed through a study of the water balance of a suburban site (Grimmond <u>et al.</u> 1986, Grimmond and Oke 1986). The size of the storage heat flux in a city is an important energy sink/source but difficult to assess. It has now come under study and attempts to evaluate it are being developed (Goward 1981; Oke <u>et al.</u> 1981; Oke and Cleugh 1987; Kerschgens and Hacker 1985).

The period has also seen the further development of numerical urban climate models. For example, Arnfield (1982) used his street canyon radiation model to predict the albedo and emissivity of a city and thence to construct its seasonal radiation budgets. Zdunkowski and his co-workers (see entries under Bruhl, Eichorn and Sievers) have constructed a fully three-dimensional urban climate model which incorporates a microscale canyon model nested within a full boundary layer model. At its most complex the street canyon model handles short- and long-wave radiation geometry, three-dimensional flow over the and within the street, and can accommodate sources and sinks of heat, moisture and pollution. It is being used to predict pedestrian bioclimates and has been compared against field data. Hjelmfelt (1982) used a three-dimensional mesoscale model to assess urban effects on airflow and to gauge the potential for uplift sufficient to induce precipitation modification. In an interesting innovation Carlson et al. (1981) and Carlson (1986) use a boundary layer model together with satellite imagery in an iterative scheme to model the distributions of thermal inertia, moisture availability and components of the surface energy balance.

Heat island research remains a central interest in the field. A departure from the norm was a study by Oke (1981) who used to simple hardware model in a cooling chamber to simulate urban-rural nocturnal cooling differences. It was able to show that under calm, cloudless conditions the maximum surface heat island in many temperate cities is strongly related to microscale controls especially street geometry. This conclusion is supported by results from Japanese and Korean cities (Park 1987b). The possible contamination of global air temperature data sets by the growth of heat islands near long-term climate stations has become an important and contentious issue in the debate regarding the ability to determine "greenhouse" warming (Jones et al. 1986; Kukla et al. 1986a,b; Wood 1988; Karl 1988). This, and issues of the effect of the warmth of cities on energy and water conservation and photochemical air pollution promise to bring heat island work into a prominent position in atmospheric research.

Finally, we can note with satisfaction a modest increase in work concerning tropical cities. During the 1980's about 7% of the total publications were from such areas, this is small but up from only 1 or 2% in the previous decade (Jauregui, pers. comm.). A further 4% was conducted in the subtropics. The work is heavily concentrated in four centres and around four people: The Peoples Republic of China (see especially Chow); India (see especially Padmanabhamurthy); Malaysia (see Sham), and Mexico (see Jauregui). By necessity the research is often descriptive but process oriented work is on the increase.

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