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Urban Climatology Applied to Urban Planning: A Postwar Knowledge Circulation Failure

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Abstract

The article discusses an instance of knowledge that failed to circulate — the application of urban climatology in town planning. This field of applied science was systematized in German-speaking universities and cities and remains most firmly established in North-Central Europe. In the decades after the second world war successive commissions and study groups of the World Meteorological Organization, the International Federation of Housing and Planning, the Confédération Internationale du Bâtiment and the International Society for Biometeorology sought to spread awareness of climatological factors among planners and architects worldwide. The article examines the organizations and individuals involved in this campaign, describes their meetings, publications and outreach, and assesses the disappointing impact. The legacy of this failure is considered in the context of present-day interest in planning for carbon mitigation and climate-change adaptation.

Introduction

Our contribution to this symposium on transnational flows of planning ideas and practices concerns a knowledge that failed to circulate. The topic was urban climatology, the region of origin was German-speaking Europe, and the transnational diffusion was attempted through global networks in and around the United Nations. The time-frame was the postwar growth era, heyday of the modernist planning ideology recalled by Healey in the opening article to our symposium (2013: 1510–26). It was a time when many aspects of Modern Movement urbanism were being taken up and routinized for better or worse — highways standards, neighbourhood unit theory, mass housing in tower and slab, pedestrian segregation, buffer landscaping. The application of climatic design principles, however, remained localized and little-known until the rise of concern over global climate change prompted fresh interest in the present century.

The science of urban climatology originates some two hundred years ago in Luke Howard's observation and analysis of meteorological differences between town and country, published serially under the title *Climate of London* (Howard, 1833). It developed as a cross-disciplinary field connecting local observational meteorology with

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physical geography, medical epidemiology and building physics. Twentieth-century contributions from thermodynamic modelling of energy fluxes and the fluid dynamics of atmospheric gases in motion brought urban climatology to a sophisticated understanding of the physical determinants of temperature, air movement, precipitation and humidity in the urban environment. In any given terrestrial location, the physical form of the city directly affects the microclimate of its outdoor spaces. Its dense structures store radiation energy, its three-dimensional forms disrupt airflow, its impermeable materials repel moisture. In climatological terms, the urban atmosphere is an anthropogenic anomaly (Erell *et al*., 2011).

Since this anomaly has a human cause, it can be shaped by human intention. Analysis of the wind-rose (the diagram showing the frequency of local wind directions and velocities) can enable land uses to be zoned so as to minimize air pollution; mapping of airflows can ensure that open spaces, whatever their other useful functions, also serve as obstruction-free ventilation paths; choices of street width and alignment can shape the incidence of sunlight and shade, and the distribution of outdoor temperatures; informed selection of low-albedo paving and roofing materials can improve energy efficiency and everyday human comfort, and reduce demand for air-conditioning. The feedback loop from weather study to town making has ancient antecedents in vernacular design cultures and in the Renaissance revival of Vitruvian wind theory. In modern times, the application of science-based climatic design has been a particular specialism of the German-speaking world, for reasons that will be discussed below. The present article discusses the circulation of this knowledge.

Techniques of anthropogenic climate management on the urban scale have acquired an extra significance in the context of global climate change (Bulkeley and Betsill, 2003). The simultaneous publication of two major '3C' (cities and climate change) reports in 2011 marked a tempo change in networking around carbon mitigation and adaptation strategies (UCCRN, 2011; UN, 2011). Urban temperatures in cities of the hot dry and hot humid zones have already risen steeply through urban heat-island (UHI) effects, and global warming trends threaten to raise them well beyond human thermal tolerance levels. Air-conditioning is a solution that aggravates the problem because of its energy demand and adverse effect on ambient outdoor temperatures. So as city leaders become alert to the risks associated with global warming there is growing interest in the precedent set by Northern European cities such as Stuttgart, Freiburg and Munich, which have tried and tested measures to leverage local microclimate (Hebbert and Webb, 2012).

Our focus here is not on the modern circulation of knowledge about city climates but on undocumented translation episodes four or five decades earlier. The research formed part of an ESRC-funded investigation into precedents and practices of knowledge transfer between science history and planning history. Based on a methodological combination of key-participant interviews and archival research, the article describes a narrative of knowledge transfer in three stages. We begin in Germany, with the systematization of local weather studies in the first half of the twentieth century, to the point where urban climatology could be said to exist as a distinct scientific branch with a state-of-the-art literature and a research community. The second and major section of the article discusses international initiatives in the postwar decades to promote awareness of the significance of climatic knowledge among planners. The third section discusses the failure of these initiatives and, in conclusion, assesses the most recent attempts at dissemination from German precedents in the context of global climate change.

Stadtklima

A seminal instance of circulating knowledge was a book published in 1904 by the Manchester businessman and social reformer Thomas Coglan Horsfall, entitled *Improvement of the Dwellings and Surroundings of the People: The Example of*

Germany (Horsfall, 1904). This dry compilation of legal-administrative notes and observations of best practice of Düsseldorf, Ulm, Stuttgart, Magdeburg, Frankfurt am Main, Cologne and Mannheim crystallized awareness of city planning as a topic of national interest, with direct political consequences in the first British town planning statute of 1909 (Sutcliffe, 1981; Ward, 2002). The 'German methods' perceived as the solution to the crisis of public health in industrial Britain included extension plans, land-use zoning, density controls, subsidized tramway systems, workers' allotment gardens, street trees, clinics, playgrounds and housing cooperatives. But it was the light and air, the wide streets and the green open spaces of German cities that most impressed Horsfall. He contrasted the environmental initiatives of their municipalities with the failure of his Manchester Corporation to prevent Trafford Park from being developed as an enormous industrial complex (the world's largest) upwind of the already heavily polluted city, precisely 'on the side of the town where it was most desirable that the town should possess land for the purpose of protecting from pollution the supply of air brought by the prevailing westerly winds' (Horsfall, 1904: 18).

Analysis of air supply and prevailing wind patterns was well established as a field of scientific investigation in German universities. Within the regional geography tradition, many doctoral investigations addressed the anomalous climate of the *Großstadt*: favoured topics included the heat-island phenomenon, air quality, the health effects of vegetation, and the complex ventilation systems of urban areas though sea breezes, topographical cold-air drainage, and the autonomous diurnal systems of the country wind (*Flurwind*) flowing into warm urban centres from the cooler surrounding countryside. A state-of-the-art review of 225 articles, mostly monographs on the climate systems of particular settlements, was systematized into the seminal text of urban climatology by the Bavarian meteorologist and geographer Albert Kratzer (1937).

The discipline had an immediate practical purpose. Air and light (*Luft und Licht*) were essential principles of German urban management. The competing traditions of town planning identified by David Harvey — the 'particularism' of Camillo Sitte's enclosed streets, and the 'universalism' of Otto Wagner's broad traffic roads — each claimed superiority on grounds of ventilation and air hygiene (Collins and Collins, 1986; Harvey 1989). Meteorological topics such as the urban heat-island phenomenon, the jet-stream effect in long, straight streets, the turbulence factor under tall buildings, the differential reflection of heat by colour (albedo effect), and the ventilation role of sea breezes were taught to Prussian and Bavarian town-planning students (Kassner, 1910; Schmauss, 1914). The technical basis for town planning included weather statistics and wind-roses so that rainwater drainage requirements could be calculated and pollution sources located downwind of living areas (Heiligenthal, 1921). According to the interdisciplinary ideology of Bauhaus, climatologists had a place alongside hygienists, economists, industrial engineers and statisticians under the leadership of 'the architect of the future' (Meyer, 1928 [1964]). Modernism's most tangible impacts upon urban form were climatological: releasing dwellings from the constraints of the street block for solar orientation, zoning land uses in relation to prevailing winds. Under the patronage of Mies van der Rohe, Ludwig Hilberseimer worked, from 1929 to 1931, on a series of planning studies of urban layouts generated solely based on considerations of solar orientation and wind ventilation (Hilberseimer, 1944; Pommer *et al.*, 1988). Kratzer's *Stadtklima* (1937) illustrates a complete separation of upwind 'dwelling-cities' from downwind 'work-cities' in the Soviet new town of Magnitogorsk, designed by Ernst May, former city architect of Frankfurt.

May went on from Soviet Russia to work in East Africa, while Hilberseimer arrived in Chicago. The Swiss modernist Ernst Egli, author of *Die neue Stadt in Landschaft und Klima* (1951), went to Ankara, and Erwin Gutkind, promoter of the 1932 Berlin exhibition *Light, Air and Sun*, joined the British Ministry of Town Planning (Grabow, 1975). Meanwhile, Martin Wagner, pioneer of ventilation through urban green space (1915), emigrated to become a lecturer at Harvard. The émigré diaspora spread awareness and experience of climatic design. The most significant migrant, from the perspective of this article, was the geophysicist Helmut Landsberg, deputy director of the Taunus Observatory in Frankfurt, who moved to the US in 1934 to take up a lectureship at Pennsylvania State University.

Over his distinguished scientific career, Landsberg taught at the universities of Chicago and Maryland, served as an applied meteorologist with the US Air Force in the second world war and, as Director of Climatology for the US Weather Bureau from 1954 to 1966, played a leading role within the World Meteorological Organization. He was a natural communicator who wrote and spoke widely to promote climate awareness among the general public. His work addressed every scale of climatology from the global down to (famously) the microclimate of beds, but he had a particular interest in the urban scale (Munn, 1986).

Landsberg recognized the importance of the foundation stone Kratzer (1937) had provided and threw his energy into building the discipline of urban climatology upon it. He was a true entrepreneur for the science and its relevance. An example is his vivid piece on microclimatology — 'a big word for the study of small-scale weather' — in the Time-Life periodical *Architectural Forum*: it demonstrates the worsening climate of the human 'breathing-line' in American cities and shows how new residential suburbs 'consciously or otherwise . . . violate every climatic principle, producing a microclimate much like that of a desert'. Like Albert Kratzer, he offered Soviet Magnitogorsk and Stalingrad as examples of 'planned climates'. He concluded:

> One of the surest ways of improving the performance of individual buildings and whole cities would be to incorporate microclimatic knowledge into their design . . . Buildings should blend harmoniously with the visible landscape but they should also recognise the invisible but important configuration of their microclimate (Landsberg, 1947: 119).

Landsberg returned repeatedly to this theme throughout his career. In a keynote address to the American Meteorological Society conference of 1972 he drew up a set of rules for urbanism — 'sound meteorological principles that must begin to penetrate the planning process' (1973: 86). His book *The Urban Climate* (1981) was written late in his life as a direct successor text to Kratzer's *Stadtklima*. Landsberg ends it with a plea for urban climatology no longer to be regarded as an academic exercise but applied through urban planning 'to mitigate or eliminate the undesirable climatic modifications brought about by urbanization' (1981: 255).

Four networks

The issue defined by the German-American Helmut Landsberg was one of knowledge circulation — circulation from Germany to the rest of the world, and from scientific meteorology to urban planning practice. Soon after the publication of Albert Kratzer's revised postwar edition of *Stadtklima* (1956), Landsberg's former employer, the US Air Force Cambridge Research Laboratories, brought out an English translation (1962). Landsberg took the lead both in establishing the climatology of cities as an internationally recognized scientific domain and in promoting its claim to be taken seriously by urban planners. The four most significant networks for this purpose were the World Meteorological Organization (WMO), the Confédération Internationale du Bâtiment (CIB), the International Federation for Housing and Planning (IFHP) and the International Society for Biometeorology (ISB). Other relevant institutions included the World Health Organization (WHO), UN-Habitat and the UN Environment Programme (UNEP), but it is the acronyms of WMO, CIB, IFHP and ISB that will dominate the remainder of this article.

WMO, founded in 1950, is a specialized agency of the UN with a secretariat in the United Nations quarter of Geneva. Its membership consists of representatives of the national weather services of member states. WMO coordinates global exchange of weather data, published its first *Statement on Climatic Change* in 1976, staged the First World Climate Conference in 1999, and today plays a key role in supporting the science base for global climate policy and the implementation of international climate conventions. Despite WMO's primary orientation to the military, aviation and agricultural sectors, its earliest engagements with anthropogenic climate change were at the urban scale. They originated in the Commission for Climatology, one of eight established at the first WMO Congress in 1951. Helmut Landsberg was active in the commission, which — through various changes of name and structure — became the launch pad from which he promoted the cause of urban climatology with the active support and involvement of WMO's secretariat, headed by the Yugoslav national Dr Slava Jovičić (Bitan, 1984). Landsberg recruited the young physical geographer Timothy Oke as WMO's official rapporteur on applications of climatology to urban problems. Oke, author of the seminal text on boundary layer climates (1978) would inherit Landsberg's role of leadership in the urban field.

WMO, representing weather services, worked in conjunction with the Confédération Internationale du Bâtiment (CIB). With a membership drawn primarily from research institutes in the building and construction sector, CIB was created with UNESCO support in 1953 as a global forum for knowledge transfer and international standardization. In 1960 CIB launched a Working Commission on Building Climatology (W4), soon expanded to embrace 'urban climatology', which continued through various mutations to provide a global network for the science. Concern for knowledge transfer was reflected in the participation of a non-governmental organization, the International Federation for Housing and Planning (IFHP), and a learned society, the International Society for Biometeorology (ISB).

IFHP was founded in 1913 by Sir Ebenezer Howard. An international NGO with a small secretariat based in The Hague, it provides a global network for housing and planning practitioners and its annual autumn congresses are major five-day events attracting more than 1,000 delegates. IFHP's agenda has mirrored the history of modern planning, from garden-city advocacy in the early twentieth century to globalization and environmental sustainability in the twenty-first. For three decades, from 1958, it tried to build a bridge between climatology and town planning. Gaetano Vinaccia, a Rome-based professor of architecture, proposed a working group to tackle the fundamental ignorance of town and building climatology among designers. The next year in Davos, IFHP joined forces with CIB and ISB to create an International Study Group for Urban and Building Climatology. This nexus continued throughout the 1980s.

Its partner ISB had been founded in 1956 under the auspices of UNESCO by Frederick Sargent II (University of Illinois) and Solco S. Tromp of the Biometeorological Research Centre at the University of Leiden. The society built a global membership — 550 from 51 countries within 10 years — and won official consulting status with WMO in 1961, UNESCO in 1962, FAO in 1963 and WHO in 1967. Biometeorology is a cross-disciplinary field — the *International Journal of Biometeorology* extends from epidemiology and physiology to agriculture and forestry, phenology (study of seasonal change in organisms) and building heating and ventilation. What it brought to urban climatology was the vital link to human health and wellbeing. Solco Tromp, for example, can be found addressing the American Meteorological Society on 'biometeorological aspects of architectural and urban planning and their significance for the thermoregulatory efficiency and physico-chemical state of the blood of human subjects' (AMS, 1972: 280–88). ISB launched an Urban and Architectural Working Group in London as early as 1960, with a brief to promote awareness of sunshine, wind and other climatic variables among architects and planners (Markus, 1960). By the late 1980s the biometeorologists were providing the main global network for urban climatology.

The intergovernmental agency, the non-governmental organization, the institute network and the learned society all had initiatives for promoting the application of climatology in the built environment. Each involved some mutual collaboration with the others and Helmut Landsberg and colleagues participated across the board in various roles, maintaining a dialogue between disparate communities of practice. To make sense of a complex picture, two vectors of activity can be distinguished. First, face-to-face gatherings of actors in meetings and conferences, underpinned by standing groups and correspondence networks; and secondly, dissemination, whether through publication of bibliographies, state-of-the-art-reviews, comparative data sheets, best-practice guides, and other types of synoptic text, or through direct initiatives to promote knowledge transfer by education, training, media and other forms of outreach.

Knowledge exchange

A remarkable series of international meetings attempted to spread awareness of urbanism's invisible atmospheric dimension. It began in 1959 with the setting up in Davos of an international study group on urban climatology involving IFHP, ISB and CIB. It became formalized in 1960 as CIB Working Group W4, later Steering Group S4. The group organized symposia in Vienna in 1965 and 1970, in Stockholm in 1972, in Zürich in 1974, and again in Vienna in 1976. The Secretary-General of WMO sent a message to the 1976 meeting affirming the importance attached to urban climate policy by the global organization (CIB, 1976). However, North America was not represented; Australia, France, Italy and Greece sent only one participant each, and the UK two, while there were 35 Austrians, 17 West Germans, nine Swiss — and one representative of the GDR.

WMO's earliest event with an urban focus was a joint symposium organized with the WHO in Brussels in 1968, involving 135 participants from 27 states. Tony Chandler's keynote address hailed it as the first international and interdisciplinary encounter between meteorologists and urban specialists sharing 'a common aim to clarify the particular nature of urban atmospheres and their relevance to urban design problems' (Chandler, 1970a: 1). Helmut Landsberg's concluding address on 'Climate and Urban Planning' was characteristically robust. He challenged planners for their ignorance of climate issues and meteorologists for their neglect of living environments and their one-sided orientation towards aviation (Chandler, 1970a: 367). With the same agenda in view he organized North America's first urban climate conference, the WMO Symposium on Meteorology as Related to Urban and Regional Land Use Planning, at Asheville, North Carolina, in November 1975. The symposium ended in a set of agreed recommendations: planning should be based upon meteorological understanding; macro-meteorological information must be supplemented by localized data and analysis; and micro-meteorological methodology must be adapted to the variety of geographical setting (Jovičić, 1976). These principles are still timely.

Landsberg tried to drive implementation through WMO's Standing Commission on Special Applications of Climatology and Meteorology. Its terms of reference were:

> the application of meteorology and climatology to problems in the field of human activities such as land planning, town planning, building specifications and architectural design, land transport, construction and other industries (Primault, 1972: 2)

For Landsberg, the commission expressed the 'natural continuum of meteorological aspects related to economic, social and environmental subjects, ranging from planning matters at regional level to city problems . . . and other living conditions within and outside buildings' (WMO, 1978: 29). Its 1978 plenary conference involved 111 participants from 58 countries and 10 international organizations. The commission appointed Timothy Oke as rapporteur on the application of climatology to urban problems; collaborated with CIB in setting up joint committees of meteorologists, architects and engineers in every member state; and joined forces in 1984 with the WHO to stage a conference in Mexico City on Urban Climatology and its Applications with Special Regard to Tropical Areas — the first international conference oriented to the global South and the urban poor.

When the focus of WMO climatology shifted towards global warming after the mid-1980s, other networks kept up the discussion of anthropogenic effects at the urban scale. In 1975, ISB initiated a permanent study group on architectural, urban and engineering biometeorology under the Israeli geographer Arieh Bitan. IFHP organized several gatherings, including symposia on The Impact of Climate upon Planning and Building in Tel Aviv in 1983, Climate, Building, Housing in Karlsruhe in 1986, and a large conference on Urban Climate Planning and Building in Kyoto in November 1989, hailed by Arieh Bitan as a breakthrough event, the first to be jointly organized by CIB, IFHP, WHO and WMO: 'the result of awareness that only by united efforts would urban and building climatology achieve recognition of its importance among scientists, engineers, planners and architects' (Bitan, 1990–91: ix).

In 1991 IFHP's Expert Committee on Urban and Building Climatology joined forces again with CIB's Working Commission on Building Climatology for an urban climate symposium in Berlin. German participants were still the largest cohort at the Berlin meeting, followed by Israelis and Japanese, but the community of specialists was growing in size and international reach, to the point where urban climatologists could think of forming their own network. The tipping point was reached at the November 1999 conference organized by ISB, WMO and UNEP in Sydney, New South Wales, Australia, on the theme of Biometeorology and Urban Climatology at the turn of the Millennium. Under the leadership of Timothy Oke of the University of British Columbia, participants decided to break away into their own International Association for Urban Climatology (IAUC). Launched initially as an email distribution list, it soon became the main channel for research communication in urban climatology. All proceedings, minutes and the organization's *Urban Climate News* were made available online. IAUC took over the cycle of international gatherings initiated by IFHP, CIB, ISB and WMO. Its first convention was in Łódź, Poland, in 2003, followed by Gothenburg, Sweden, in 2006, when an official 'working arrangement' was set up with WMO. The 2009 conference in Yokohama, Japan, saw the launch of an online bibliography of urban climatology, also sponsored by WMO. IAUC president Gerald Mills of University College Dublin hosted the 2012 congress in the Irish capital (see Table 1).

Dissemination

From the outset, urban climatologists saw the need to reach beyond the confines of meteorological science and speak directly to those who shaped the urban environment. WMO supported many such initiatives through its technical publications series (Jovičić, 1984). A characteristic example would be Helmut Landsberg's introduction on *Weather, Climate and Human Settlements*, written for delegates at the first UN-Habitat conference in 1976 (Landsberg, 1976). Landsberg also commissioned the British geographer Tony Chandler, author of *The Climate of London* (1965), to prepare a WMO bibliography on urban climate (Chandler, 1970b) and a state-of-the-art-review, *Urban Climatology and its Relevance to Urban Design* (Chandler, 1976). Chandler lucidly summarized the physical science. His characterization of planning, however, was fanciful, simplistically exaggerating the extent of control exercised by urban designers over city form. It illustrated the difficulties of knowledge transfer. Scientists found it easiest to engage with planning as practised in the Soviet bloc, where meteorological considerations could be incorporated into centralized formulae for the production of the built environment, as in the *Matrices for land-use, town and building planning as related to climatic parameters* drawn up by J. Kolbig of the GDR, which WMO published jointly with CIB (Kolbig, 1972).

Helmut Landsberg's opening address to CoSAMC's 1st meeting in Bad Homburg called for a dual education programme in planning and climatology to encourage mutual interdisciplinary understanding (WMO, 1973: 2–15). Among the commission's

Table 1 Principal international meetings in urban climatology

Location, Date and Name	Agencies	Actors	Outcomes and References
Brussels, 1968, Conference on Urban Climates	WMO, WHO and CIB	T. Chandler, H. Landsberg, J. Page, T. Oke	'Mutual education' of climatologists and planners (Chandler, 1970a)
Asheville (CT), 1972 12th Conference on Applied Climatology	WMO	H. Landsberg (organizer)	Better technology transfer between WMO and national meteorology services to support urban planning
Stockholm, 1972, Teaching the Teachers	CIB, WMO and IFHP	B. Frommes	University questionnaire
Philadelphia, 1972, 2nd Conference on the Urban Environment and 2nd Conference on Biometeorology	AMS	H. Landsberg, S. Tromp	
Bad Homburg, 1973, 1st session of CoSAMC	ISB, CIB	H. Landsberg (presiding), R.H. Clements, W.H. Weihe	Strengthening links with CIB and ISB
College Park (MD), 1975, 7th International Congress of ISB	ISB	H. Landsberg, S. Tromp	
Vancouver, 1976, First UN-Habitat Conference	UN-Habitat	H. Landsberg, J. Baumüller, T. Chandler	City of Stuttgart's film *Urban Climate and Development*
Vienna, 1976, Planning and Construction in Conformity with Climate	CIB, WMO, IFHP, ISB	B. Frommes, E. Liepolt, S. Jovičić	CIB Report No. 15, *Meteorological Information for Architects and Building* (Kolbig, 1972)
Geneva, 1978, 7th Session of CoSAMC	WMO, ISB	M.K. Thomas (president), H. Landsberg (ISB), F. Becker (ISB)	WMO/WHO collaboration on human biometeorology
Washington, 1982, 8th Session of Commission for Climatology and Applications of Meteorology	WMO, ISB, IFHP	M.K. Thomas, H. Landsberg (ISB)	First appointment of rapporteur on urbanization in developing world
Geneva, 1983, Expert meeting convened by WMO	WMO, IFHP, UNEP, ISO, WHO, UNECE	T. Oke, R. Taesler	Workshops, missions and 'focal points' for urban and building climatology within national meteorology services; brochures targeted at 'decision makers, planners, architects, builders and engineers' (WMO, 1983)

Table 1 Continued

Location, Date and Name	Agencies	Actors	Outcomes and References
Tel Aviv, 1983, 2nd International Planning and Building Symposium	IFHP	A. Bitan, S. Jovičić and T. Oke	Dr Slava Jovičić celebrates WMO commitment to urban climatology (Bitan, 1984)
Mexico, 1984, International Conference on Urban Climates in Tropical Cities	WMO, WHO, IFHP and CIB	T. Oke, H. Landsberg, A. Bitan, B. Givoni, R. Bornstein, T. Kawamura and I.R. Imamura	Holding an international year of climate in 1992 with the emphasis on planning applications; prioritizing tropical research (Oke, 1986)
Geneva, 1985, 9th Session of the Commission for Climatology	WMO, IFHP, CIB and ISB	J.L. Rasmussen (president), A. Bitan (observer for IFHP), H. Landsberg (for ISB), V.B. Torrance (for CIB)	Growing concern for global climate change; decision to focus on developing world
Karlsruhe, 1986, 3rd International Symposium: Climate, Building, Housing	IFHP	K. Höschele (organizer) A. Bitan, H. Mayer	Too many organizations, too little cooperation
Moscow, 1987, New Developments in Building Climatology	CIB	J. Page	CIB to set up working groups with ISO and computerize its data
Kyoto, 1989, 4th International Conference: Urban Climate, Planning and Building	CIB, IFHP, WHO,WMO	Y. Nakamura, A. Bitan	'Breakthrough' conference, 360 participants, first to be organized cooperatively by all four international organizations (Bitan, 1990–91)
Berlin, 1991, Planning Applications of Urban and Building Climatology	IFHP, CIB	K. Höschele A. Bitan	The only planning papers were from Munich, Heidelberg, Waldkirch, Kassel and Cologne (Höschele, 1992)
Dhaka, 1993, Meeting on Tropical Urban Climates	WMO, WHO, IGU, UNEP	T. Oke, A. Bitan	Tropical urban climate a key activity within WMO long-term plan
Essen, 1996, International Conference on Urban Climate	Essen University, ICUC	T. Oke, S. Grimmond, W. Kuttler, E. Jauregui, H. Mayer, D. Pearlmutter, A. Bitan	Launch of IAUC, initially as an e-mail contact list
Kobe, 1997, German-Japanese Meeting of Experts: Climate Analysis in Urban Planning		J. Baumüller	Launch of Stadtklima information network and IT tools

Sydney, 1999, International Congress: Biometeorology and Urban Climatology at the Turn of the Millennium	ISB, IAUC, WMO, UNEP	G. Mills, T. Oke, S. Grimmond, J. Arnfield, B. Bornstein	Breakaway of IAUC (de Dear *et al*., 2000)
Location, Date and Name	**Agencies**	**Actors**	**Outcomes and References**
Davis (CA), 2000, 3rd AMS Symposium on the Urban Environment	AMS	S. Grimmond, B. Bornstein, M. Roth, W. Kuttler, J. Arnfield, T. Oke, M. Kanda, H. Mayer	
Norfolk (VA), 2002, 4th AMS Symposium on the Urban Environment	AMS	S. Grimmond, T. Oke, B. Bornstein, M. Roth, W. Kuttler, H. Mayer	
Łódź, 2003, International Conference on Urban Climate (ICUC 5)	IAUC, WMO	T. Oke, G. Mills, S. Grimmond	Strong focus on modelling, but little on policy application (Kłysik *et al*., 2003)
Vancouver, 2004, 5th AMS Symposium on the Urban Environment	AMS	T. Oke, S. Grimmond, H. Mayer, M. Roth	
Seattle, 2004, Annual Meeting of AMS: Planning, Nowcasting and Forecasting in the Urban Zone	AMS	B. Bornstein, M. Kanda, S. Grimmond	
Gothenburg, 2006, International Conference on Urban Climate (ICUC 6)	IAUC, WMO, AMS, IGU, ISB	T. Oke, S. Grimmond, G. Mills, M. Roth, M. Kanda, J. Arnfield, B. Bornstein, J. Page, A. Bitan	Establishment of official 'working arrangement' between IAUC and WMO
San Diego (CA), 2007, 7th AMS Symposium on Urban Environment	AMS, NOAA, NASA	B. Bornstein, S. Grimmond	
Yokohama, 2009, International Conference on Urban Climate (ICUC 7)	IAUC, WMO, ESA, IGU, AMS, PLEA	D. Pearlmutter, S. Grimmond, H. Mayer, G. Mills, T. Oke, M. Kanda, M. Roth	WMO-sponsored online bibliography of urban climatology
Keystone (CO), 2010, Symposium on the Urban Environment	AMS	H. Mayer, T. Oke	Calls for mutual education between meteorologists, climatologists and planners
Dublin, 2012, International Conference on Urban Climate (ICUC 8)	IAUC, WMO	G. Mills (chair)	343 papers and 130 posters, including 120 on policy applications of urban climate science

subsequent initiatives to promote education, training, and information transfer were international training seminars in France and the USA, schemes for 'roving instructors' in Canada and the USSR, and a joint action plan with the WHO to provide training for public officials and to:

> develop suitable publicity activities including public meetings, press conferences, personal contacts, articles, posters and films with a view to influencing both politicians, government officials and the general public to create a favourable climate of public opinion in which to make progress in the field (WMO, 1984: ix).

Promotion of climatology in architecture and planning education was a recurring theme of all the networks. CIB, through its W4 working commission, held a conference in Stockholm in 1972 on Teaching the Teachers, which highlighted the lack of climate science in the planning curriculum, and the follow-up meeting in Vienna in 1976 resolved to promote this missing dimension in the education of planners, architects and decision makers. IFHP took the lead. In 1977, Steering Group S4 had separated from CIB to operate wholly under IFHP auspices, where it was known as the Standing Committee on Urban and Building Climatology. Its network of correspondents included two Yugoslav experts, two Japanese, three Israelis, three French, six Austrians, eight Swiss and 29 Germans (all FRG). Directing their advocacy towards the educational sector, they sent out a questionnaire in 1978 to 206 European universities and technical colleges, enquiring if the architecture and planning curriculum contained lectures on climatology, and if so, given by whom, and in what context. They eventually secured 75 responses, mostly negative. Coverage was found to be 'rather casual, unbalanced and incomplete' — one school said it taught the necessary material in two hours (IFHP, 1980: 3).

To plug the curriculum gap, IFHP issued a 27-page list of all the topics that planners and architects should understand. *Fundamental Knowledge in Urban and Building Climatology* (Frommes, 1980) was a minutely detailed catalogue including some 70 entries on wind and 40 on rain ('drop size under different conditions'; 'long lasting rain, heavy rain, driving rain, tropical rain, monsoon', and so on). Over 1,500 copies were sent out unsolicited to the universities targeted in the 1978 questionnaire — one each for the dean, the librarian and the person teaching architecture: most disappeared without trace. IFHP continued to give priority to publications, through working groups on 'climate data books', 'fundamental knowledge', 'interdisciplinary cooperation' and 'guidelines for climate-adapted construction'.

The standing committee noted the absence in most countries of 'a simple, easily understandable manual of climatology for planners'; the science was known but it was not being applied — 'now is the time for diffusion' (Frommes, 1982: 36). Helmut Landsberg continued to lead from the front, as author and spokesperson. His monograph, *The Urban Climate* (1981), was published as Volume 28 in the International Geophysics Series of the Academic Press. Completed towards the end of his academic career, the book could be criticized for its limited appreciation of the shift towards numerical modelling in state-of-the-art boundary layer research, but its treatment of urban planning was fresh and pertinent. For Landsberg, urban climate knowledge was not an academic exercise but a branch of applied knowledge that should be used by planners for practical purposes of flood prevention, urban heat-island mitigation, wind, rain and snow management, and for effective use of green space to enhance air quality and human comfort (Landsberg, 1981: 255–61). This message of practical utility was also reinforced by authors from Israel, one of the few countries outside Germany where urban climatological research was being applied in practice — for example, by the Israeli Defence Force in planning military bases after the 1967 war (Bitan, 1984: 19–21). After Helmut Landsberg's death, Arieh Bitan of Tel Aviv University took the lead in advocacy, publishing some IFHP symposia articles with the Lausanne-based Elsevier Sequoia under the title *Applied Climatology and its Contribution to Planning and Building* (Bitan, 1984), and others through the Pergamon journal *Energy and Buildings* (Bitan, 1990–91). His colleague Baruch Givoni of the Haifa Technion published a classic text on climatic design (1969), updated three decades later as *Climatic Considerations in Building and Urban Design* (1998).

Perhaps the most successful example of dissemination was the documentary *Urban Development and Urban Climate* commissioned for the UN-Habitat conference in Vancouver in 1976. Made on behalf of the Federal German Republic by ARPA Films of Munich, the movie showed the everyday work of the climatology unit of the City of Stuttgart.[1] Anne Whiston Spirn's book *The Granite Garden* (1984) describes its remarkable impact on one American municipality. The wind-blown city of Dayton, Ohio, decided to emulate Stuttgart's climate-management approach. They borrowed a climatologist from the US Forest Service, made weather measurements, had two Parks Department employees build a scale model of the downtown area, got it tested in the MIT wind-tunnel, replaced asphalt with turf blocks in parking lots, developed a tree-planting strategy and launched an international urban-climate newsletter (Spirn, 1984: 77–82). Yet the impacts were localized and short-lived. Timothy Oke, who regularly showed the Stuttgart film to his urban climatology class, commented that the biggest stumbling block for students was the German acceptance of a degree of planning control unthinkable in North America (Oke, 1984).

The elusive breakthrough

When he opened the 1983 urban climatology symposium in Tel Aviv, Arieh Bitan expressed an often-repeated hope:

> I hope that this International Symposium and the others that will follow in its wake, will make their contribution and result in a breakthrough whereby the climatic factor will be integrated into every planning project and applied climatology for planning and building purposes will thus have arrived (Bitan, 1984: viii).

The feasibility of such a breakthrough could be demonstrated from the continuing example of Germany. Centres of research excellence in Munich, Karlsruhe, Kassel and Freiburg kept up a flow of monographs into aspects of city climate. The quality of urban climate merged seamlessly with other aspects of the country's strong environmental protection (*Naturschutz*) movement (Chaney, 2004). The 1965 federal planning law or *Bundesraumordnungsgesetz* provided for the integration of climatic information into spatial plans, and the 1976 federal law on nature protection (*Bundesnaturschutzgesetz*) included a requirement to prevent detriments to the climate, in particular the local climate. Examples of climatic urbanism could be found in cities of every scale — Berlin, Bochum, Freiburg, Kassel, Heidelberg, Munich.

The Swabian capital Stuttgart was the city that led the field both in terms of having in-house meteorological expertise and of putting it to practical effect through building control, urban design and landscape planning (Schirmer, 1984; Höschele, 1992). Stuttgart's locally developed techniques for mapping thermal distributions, cold air lakes and flows, wind patterns and pollution concentrations in a climate atlas (*Klimaatlas*) would eventually be incorporated into VDI 3787–1, a national standard promulgated by the Institute of German Engineers, and widely applied within Germany (Baumüller and Reuter, 1995; Hebbert and Webb, 2012).

It remained obstinately difficult to spread these practices more widely. As late as 1991, the only case studies offered to the IFHP/CIB conference on Planning Applications of Urban and Building Climatology were Munich, Heidelberg, Waldkirch, Kassel and

1 The Stuttgart documentary *Urban Climate and Development* is available for viewing online at http://www.sed.manchester.ac.uk/architecture/research/csud/workshop/media.

Cologne (Höschele, 1992). After two decades of striving to promote international awareness of urban climate, IFHP's standing committee described itself as a 'voice in the desert' (Frommes, 1982: 32). In his role as WMO rapporteur on urban climatology, Timothy Oke, the leading authority on boundary layer dynamics, compiled four periodic state-of-the-art reviews, each longer than the previous, but could trace no growth in the application of the science: 'despite some notable exceptions, little of the large body of knowledge concerning urban climate has permeated through to working planners' (1984: 1). He blamed the discipline for failing to provide what decision makers needed — practical predictive tools that would enable them to configure green space, orient roads and buildings, and optimize the height-width ratio of street canyons in relation to climatic objectives such as thermal comfort, energy conservation or pollutant dispersal. A meeting at WMO's Geneva headquarters in December 1985 (attended by Arieh Bitan on behalf of CIB and IFHP, and Helmut Landsberg for ISB) concluded that the failure to apply the discipline of climatology to the built environment could be attributed to the continuing disconnection between national meteorological services and the planning, design and construction professions (WMO, 1985). The verdict was clear. While climate science continued to advance, supported by progressively more sophisticated measuring, monitoring and modelling technologies, its application to urban planning, Germany excepted, had stalled.

Discussion

The failure of knowledge transfer in urban climatology has contemporary relevance and deserves to be more widely known.[2] The application of science is a process of translation. It depends upon intermediaries to demonstrate potential, entrepreneurs to extend networks into fresh territory, and legal, political and economic incentives to consolidate the application. The urban climate campaign of the postwar decades successfully achieved high-level endorsement through WMO, WHO, CIB, UNEP and other international networks, yet failed to build — in Healey's term (2013: 1510–26) — a circuit of knowledge. Tried and tested German precedents of applied climatology were not widely considered as part of state-of-the-art town planning. They were not taught or researched in planning schools. Most actors remained unaware of them.

Several factors were at play here. Despite its origins in the *Ville Radieuse,* modernist design paid more attention to the enclosed realms of buildings, malls, atria, walkways and motor vehicles than to outdoor space. Architects, defining their role in aesthetic terms, tended to relinquish professional control over environmental performance to heating, ventilation and air-conditioning engineers. The emerging field of urban design studied street atmosphere from a visual and psychological angle, but climatic analysis was almost unknown. Mainstream planners were becoming more concerned with the social policy agenda than the physical habitat. The bad repute of 'environmental determinism' discouraged interest in the causal effects of design decisions. Neither the thematic bibliography on urban heat islands published by the Conference of Planning Librarians (Berlin, 1972) nor WMO's bibliography on climatology and urban design (Chandler, 1976) contained a single contribution by a planning specialist. In its advocacy of *Fundamental Knowledge on Urban and Building Climatology* (1980) IFHP was preaching to deaf ears.

In socio-technical terms, urban climatology is particularly dependent upon local framing devices. Variables such as solar angle can be mathematically predicted on a global basis, and data tables or matrices were soon available with this information (Kolbig, 1972; Page and Lebens, 1986). But air-movement and temperature flux depend upon complex characteristics of the urban landscape that are location-specific, and

2 This is the topic of a separate article by Michael Hebbert and Vladimir Jankovic (2013), entitled 'Cities and climate change: the precedents and why they matter' in *Urban Studies* (50.7).

require localized observation and analysis. Local weather studies were strong in Germany for historic reasons linked to strong academic traditions of regional geography, the *Heimat* concept and a cultural awareness of weather sensitivity (*Wetterfühligkeit*). More concrete factors were the relatively recent merger of independent territorial meteorology services into the *Reichswetterdienst* (Reich Weather Service) — this occurred only in 1934 — and the postwar decentralization of West Germany, which required the *Deutscher Wetterdienst* (DWD) from its foundation in 1952 to provide meteorological services to regional and local levels of government.

The local circumstances that facilitated science application in German, Swiss or Austrian towns were rarely found elsewhere. The orientation of most national weather services was towards the aviation, agricultural and defence sectors, and public weather forecasting. The very basis of meteorological data collection had an anti-urban bias, since weather measurements came from level grass-covered sites away from the distorting influence of buildings. As the technical basis of forecasting shifted from physical compilations of local station data towards systematic models hosted in central computers, the organization of meteorological services tended to centralize. Even if urban planners had wanted to pay more attention to the wind-rose, rainfall distributions and temperature gradients, data were lacking for most cities outside the German-speaking world. The planning literature contains some isolated examples involving specially commissioned investigations, such as the sky-view factor analysis using 180° fish-eye lens photography undertaken by the Berkeley Environmental Simulation Laboratory in Toronto, or the wind-tunnel and shadow simulations run by Berkeley in support of San Francisco's tall-buildings policy, or MIT for Dayton, Ohio, but such work was expensive, laborious and unusual (Spirn, 1984; Bosselmann, 1998).

How do things stand today? Brazel and Quatrocchi (2005: 778) describe the application of research findings of urban climatology in building design and urban environmental planning as 'beginning to emerge but not yet widespread'. German-speaking cities still set the benchmark, other European cities lag, the fast-growing settlements of the global South have hardly begun to define the issue (Emmanuel, 2005). But certain factors that worked against the urban climatology actor-network may now be shifting in its favour. On the science side of the equation, the creation of IAUC has given the discipline a single network and the capacity to act and influence. The methodological basis of meteorology continues to advance. Lightweight sensors that capture and transmit data are bringing down the cost of weather observation. Multi-scalar computer models linked to GIS systems and three-dimensional modelling of urban form facilitate high-resolution climate mapping. Biometeorological modelling now provides a methodological link to the demographic base and to assessment of public health impacts (Erell *et al*., 2011; Hebbert *et al*., 2011).

At the same time, there has been a shift on the demand side. Global climate change forecasts have triggered a new type of local climate awareness — the '3C' phenomenon of city-scale response to global climate change (UN, 2011). New York and other world cities have built mutual networks to share best practice in researching and responding to the risks of global warming (UCCRN, 2011). Governments such as the State of California have legislated for local action to mitigate carbon emissions and enhance resilience to climate change (Calthorpe, 2011). Post-peak-oil, different styles of thinking are percolating into the thought-world of the planning profession, with a revival of early twentieth-century interest in the consequences of urban form, and a reinstatement of local design variables — street layout, land-use patterns, density, landscaping — at the heart of planning theory (Birch and Silver, 2009; Barton *et al*., 2010).

In this context, the everyday practice of climate mapping in German municipalities is attracting new interest. This time the impetus is not from international knowledge networks such as WMO, CIB, IFHP and ISB, but from the grassroots level. Ng (2012) describes the application of *Klimaatlas* methodology by oppositional groups in Hong Kong, a reaction against the deterioration of street-level ventilation as massive waterfront developments block the circulation of sea breezes. Ren *et al*. (2011) trace the growing interest among municipalities in Japan and elsewhere in Southeast Asia in climate mapping as a basis for regulatory measures to bring thermal relief to hot, humid cities. Germany remains the prime repository of experience and expertise; it seems that the techniques of *Stadtklimatologie* are at last beginning to circulate.

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