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# Climatology for city planning in historical perspective

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### ABSTRACT

The paper offers a historical perspective on the application of urban climatology in city planning. Correcting the apparent misunderstanding that urban climate science is an 'infant' and untried discipline, its evolution since the mid twentieth century is described, with particular attention to the history of dialogue with planning and urban design. The narrative describes an initial phase of optimism in networks for international cooperation, followed by disappointment at their limited impacts upon planning practice. Several institutional factors are discussed, as well as the suggested paradox that scientific progress from place to process studies may have inhibited communication in the short term, though in the long run it was to lay the technical basis for a much wider application of climate knowledge in planning. The use of GIS-based maps is seen to offer a potentially useful means of mediation between atmospheric analysis and land use recommendations. The northern European origin of 'Klimaatlas' technique is explained as well as its diffusion to diverse climatic and institutional settings. The paper concludes by underlining the relevance of this history to contemporary urban response to global climate change.

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## 1. Introduction

In the aftermath of ICUC8 it was surprising to read in *New Scientist* that 'the science of urban climate control is still in its infancy and until recently only limited efforts had been made to understand the details of city climate' [Austen \(2013\)](#)

ICUC8 was in fact the eighth major international meeting on urban climate since 1989 and continued a sequence of scientific gatherings that has run for more than fifty years – hardly an infancy. Seminal texts – [Kratzer \(1937\)](#), [Oke \(1978\)](#), [Landsberg \(1981\)](#) – span the middle years of the last century ([Kratzer, 1937](#); [Oke, 1978](#); [Landsberg, 1981](#)). Although the knowledge network of the International Association for Urban Climates (IAUC) took its present shape only in 2000, its infancy occurred decades earlier at meetings such as the Brussels symposium on *Urban Climates and Building Climatology* of 1968, when WMO and WHO first convened specialists from many disciplines with the aim of understanding the urban atmosphere, and applying this knowledge for its improvement.

On closer reading, it appeared that *New Scientist* was looking for a different category of innovation: techniques such as subterranean popsicles drilled under Ulan Bator to store winter freeze-water for summer cooling; heat-reflective roofing materials to reduce dependence on air-conditioning in Athenian heat-waves; the installation in a Taiwanese park by a French landscape architect of electrical dehumidifiers and light-absorbing pavements incorporating catalysts intended to break down atmospheric pollutants; thermochromic paving in Tirana; and showcase eco-developments such as Masdar in the Abu Dhabi desert; PlanIT Valley in Paredes, Portugal, and Abu Dhabi's Mina Zayed waterfront, featuring – apparently – such marvels as 'a cylindrical building wrapped in a large moving curtain that follows the sun, providing all-day shade for an outdoor park at the center of the building' ([Austen, 2013](#)). Leaving aside the novelty factor of such inventions, *New Scientist* was expressing a widely-shared misconception about urban climate science. Public policy documents such as UN-Habitat, consultancy reports such as Atkins and academic texts such as [Bulkeley \(UN-Habitat, 2013; Atkins, 2013; Bulkeley, 2013\)](#) tend to take the millennium as their starting-point, discounting the previous half-century of efforts, albeit often disappointed, to apply climatic knowledge, and the precedents they offer today's decision-makers in terms of every-day planning tools rather than exotic technical fixes.

The present paper retraces this history from the mid twentieth century. Antecedents of urban climatology go back to the vigorous trend of empirical investigation prompted by the phenomenon of the nineteenth-century city: Luke Howard (1772–1864) measuring *The Climate of London*; Émilien Renou (1815–1902) the atmospheric epidemiology of Paris; Max Von Pettenkofer (1818–1901) the bioclimatology of Munich ([Howard, 1833](#); [Janković, 2013](#)). Air pollution and ventilation were as great a concern as water supply, drainage and sewerage for Victorian reformers, but the harm caused by private chimneys and funnels was harder to address than water-borne sanitation. The twentieth-century brought the promise of cleaner energy and transport technologies and greater confidence in collective regulation. The new discipline of town planning (French *urbanisme*, German *Städtebau*) aimed to bring self-awareness and stewardship into the process of town building. 'Planning' implied both political acceptance of intervention and sense of respect for rational evidence-based policy-making. In 1904 the prologue to the opening issue of the world's first planning magazine, *Der Städtebau*, included humidity, temperature, air quality and ventilation among the many technical factors to be considered ([Collins and Collins, 1986](#)). But early attempts to incorporate climatic consideration into town planning were limited to crude generalizations about regional weather patterns and prevailing winds ([Egli, 1951](#); [Hilberseimer, 1944](#); [Taylor, 1950](#)). Not till the publication of Albert Kratzer's *Stadtklima* in 1937, revised and expanded in 1956, was the relation between built form and urban boundary layer presented in anything like its true complexity ([Kratzer, 1937](#)). As a student of the geographer Edward Fels, pioneer in the scientific study of anthropogenic environmental impacts, Kratzer emphasized above all the man-made character of the urban climate: volcano-like in its effects, as he put it, yet a product not of nature but of human agency, and all the more significant for being unintended.

In the basic paradigm of urban climatology the independent variable was the built environment of the city, and its human use. Though man-made, urban form is itself inadvertent, a by-product of multiple independent decisions. As Kraus wrote in the *Quarterly Journal of the Royal Meteorological Society* of 1945:

'clothes and houses constitute a deliberate attempt by men to create an artificial climate within a limited region. In their towns men have also altered the natural climate to a remarkable degree, but in this case the alterations are only the accidental results of activities which are directed towards quite different goals' [Kraus \(1945, p. 402\)](#)

In this context urban climatology could be seen as a service discipline, extending the scope of communal foresight into the ambient atmosphere, mitigating adverse anthropogenic forcing factors and encouraging beneficial effects. The central argument of Albert Kratzer's *Stadtklima* was that urban climate did not need to be accepted as a fact but could, and should, be influenced for public benefit. How did this argument fare in practice?

## 2. Optimism

The aftermath of the Second World War saw widespread acceptance of the concept of scientific planning. Entirely new structures for knowledge exchange were established under the aegis of the United Nations. Town planners were at the forefront of transnational knowledge transfer and, as Rosemary Wakeman shows, their expectations for social and urban reform were enormous ([Wakeman, 2014](#)). The 1951 re-launch of the International Meteorological Organization (1873) as a UN agency, the World Meteorological Organization, implied a turn towards applied climatology. In the early years the demands of the aviation for synoptic meteorology outweighed most other considerations, but from the mid 1960s WMO became actively involved in civil applications such as the promotion of climate-aware city planning and building design. Important milestones were the 1972 Stockholm UN Conference on the Human Environment, preceding the launch of the United Nations Environment Program (UNEP), and the 1976 Vancouver Conference on Human Settlements, which led to the launch of UN-Habitat. C.C. Wallén, Swedish chief of WMO's Scientific and Technical Division from 1967, commissioned two young British climatologists to provide state-of-the-art reviews, Tony Chandler of University College London on urban scale applications and John Page on buildings. Page was a pioneer in the application of climate science to the built environment ([Page, 1970](#)), leading the way with the architecture and planning curricula of the University of Sheffield. He called on meteorologists world-wide to engage in face-to-face dialogue with designers 'so they can play a more dynamic role in future in urban development, in contrast to the traditional passive role of meteorologists as suppliers of standard data to other decision-makers who have seldom been able to make effective use of such data' [Page \(1976, p. 63\)](#). Similarly, Tony Chandler's *Urban Climatology and its Relevance to Urban Design*, published as WMO Technical Note 149 ([Chandler, 1976](#)) stated in boldest possible terms the claim for climate as a design factor in planning at neighborhood and city-wide scales. His summary, translated into French, Russian and Spanish, merits quotation in full:

'Optimization of the indoor climate is a most important and long recognized role of the architect. In contrast, although not entirely neglectful of climatic considerations, urban planners have, until comparatively recently, only rarely considered climate among the several constraints upon urban design. The layout of cities has in most cases been dictated, or almost accidentally created, by a series of mainly political, social and economic decision-making processes, often over many centuries. The reason for the neglect of climatic considerations has been partly the relative youthfulness of the science of urban climatology and partly the relatively weak communication links that presently exist between climatology and planning. But faced with the exponential growth of the world's population and the accelerating pace of urbanization it is clear that our cities must, where appropriate, be purposefully planned in order to optimize the environment of urban areas and avoid a series of structural and functional design failures. Climate is an essential element in this planning'.

To reinforce that message C.C. Wallén provided all delegates to the 1976 Vancouver conference with a special WMO report, *Weather, Climate and Human Settlements* ([Landsberg, 1976](#)). It was authored by the man Wallén later described as 'the world's most famous climatologist' ([WMO, 1993](#)), former Director of Climatology for the United States Weather Bureau, and a tireless advocate for applied climatology at every scale. Helmut Landsberg spent almost four decades lobbying for scientific understanding of inadvertent and adverse climatic modification in modern cities. *The Urban*

*Climate* (1981), published as volume 28 in the International Geophysics Series, ends with a plea that the science of urban climatology should not only be pursued intellectually but applied in the practice of city planning ‘to mitigate or eliminate the undesirable climatic modifications brought about by urbanization’ (Landsberg (1981, p. 255)). Born and trained in Germany, he was shocked by the environment deterioration of the modern American city and repeatedly sought to show how climate-awareness could enhance urban efficiency and well-being. His list of ‘sound meteorological principles that must begin to penetrate the planning process’ (Landsberg, 1973) loses none of its relevance forty years on: reduce in-town automobile emissions; promote green-space for evapo-transpirational cooling and run-off reduction; stop building on flood-plains; do not sacrifice shade trees for traffic flow; recognize urban heat as a potential health hazard; beware aggravating the outdoor heat load through reliance on indoor air-conditioning.

Landsberg pursued this agenda at the global level through WMO. As chair of the Committee for Special Applications of Meteorology and Climatology from 1971 to 1983, he worked with WMO Secretary Slavka Jovičić to promote applied urban climatology within WMO and collaboratively with the Confédération Internationale du Bâtiment (CIB) and the International Society for Biometeorology (ISB) (Jovičić, 1984). These initiatives included conferences, workshops, publications, film, educational liaison, and linkage with funding councils and professional bodies. The campaign for knowledge transfer produced texts such as Baruch Givoni’s *Urban Design in Different Climates* (Givoni, 1989) offering detailed and still-valuable recommendations for design in different climatic zones. It involved leading scientists such as the British-Canadian climatologist Tim Oke, whom Landsberg invited in 1970 to succeed Tony Chandler in the important role of *rapporteur* on urban climatology to the WMO Commission on Climatology. The author of *Boundary Layer Climates* (1978) would play a seminal part not only in the development of the science but also in its institutional formation as the founder of the International Association for Urban Climate, and in promotion of knowledge transfer to planning (Oke, 1978; IAUC, n.d.).

Spanning the whole time-frame of our narrative, Oke could be said to have brought the era of optimism to its climax in 1983 when with Roger Taesler he presented an expert report on tools for applied urban climatology to a meeting at WMO’s Geneva headquarters attended by WHO, IFHP, UNEP, the International Organization for Standardization (ISO), and the UN Economic Commission for Europe (UNECE). Recommendations for action included workshops and missions to promote cooperation with users; urban climate focal points within national meteorological services; preparation of material documenting climate effects on buildings and settlements; and a push on educating both meteorologists and users ‘about the potential economic/social/ecological benefits of considering climate as a factor in various activities related to land use, urbanization and building’ (WMO, 1983, p. 3). Arieih Bitan echoed the same hope in his opening address to the 1983 international urban climatology symposium (a forerunner of the ICUC events) in Tel Aviv. He looked forward to an imminent breakthrough ‘whereby the climatic factor will be integrated into every planning project’ (Bitan, 1984, p. viii). Nowhere was the need more urgent than in cities of the global south, where the environmental pressures of rapid urban growth, wide social disparity and weak governance were compounded by the replacement of traditional building types with ubiquitous concrete frame construction. In November 1984 the WMO held its first joint conference with the World Health Organization (WHO) in Mexico City. Once again, delegates passed a resolution on the need for public officials, architects and planners to receive training in urban climatology. They resolved to

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

### 3. Disappointment, and its causes

After so much expectation came disappointment. Progress was poorest in those cities of the global South where researchers were documenting the fastest rates of urban climate change (Chow, 1992).

With certain exceptions, considered below, the networking initiatives floundered and outreach to universities failed (Hebbert and Janković, 2013). The generality of applications resemble a platoon marching on the spot, hardly progressing beyond the declarations agreed by delegates at Landsberg's WMO's symposium of November 1975 (WMO, 1976). There has been much discussion of this impasse (Eliasson, 2000; Erell, 2008; Mills, 2006; Oke, 1986); here we draw out four factors: first, the limitations of international standardization; second, indifference on the part of national meteorological agencies; third, unreceptiveness of urban decision-makers; and last, the changing character of the science itself.

Transnational knowledge flows in the postwar decades were based on a shared discourse of modernism. Global actors such as WMO, WHO and their partners saw city-building as a process of clean-slate design, unconstrained by local conditions, traditions and preferences (WMO, 1961). Experts such as Jachowicz (1963) and Kobysheva (1992) sought to define 'proper standards' that could be applied to 'every town' and 'every village' (Jachowicz, 1963; Kobysheva, 1992). Such top-down rationality proved illusory when applied to national plans and all the more so in a context of multi-lateral, multi-level governance. At a high-level meeting of the CIB with WMO, IFHP and ISB the British solar design expert Patrick O'Sullivan went on record to describe the setting of international meteorological guidelines for planning as 'senseless' (CIB, 1976). Idiosyncratic combinations of regional weather, landscape geography, site topography, urban building patterns and civic culture resisted standard-based solution: they required local interpretation, or as Corburn puts it, 'co-production' of knowledge by science producers and policy users together (Corburn, 2009).

Translation from global initiative to local implementation depended crucially upon supportive action at state level. National meteorological services (NMS) were the key intermediaries since they held the necessary data, all too closely in many jurisdictions, and employed a majority of the professional meteorologists and climatologists. Yet in general they proved unresponsive to the promise of urban climatology. Their institutional positioning as national government agencies tended to protect established priorities – weather forecasting and the military, agricultural and industrial sectors – at the expense of outreach to local governments. If anything, the institutional bias tended to become more centralized as traditional weather observatories and service outposts were regrouped into unitary services, supported by giant computing power – the demise of the UK Met Office's regional network being a case in point. Consequently, commitments to municipal-scale service agreed at the international level in Geneva had low priority for participating NMS. For example, WMO's Tropical Urban Climate Experiment (TRUCE) initiated in Mexico City in 1984 was intended to produce a global data-base of tropical urban climates, develop models capable of simulating, and devise practical guides to promote climate-aware design (WMO, 1984; Maunder, 1992). National representatives voted almost unanimously in WMO Council to back the TRUCE initiative in 1989: yet hardly any donated financial or personnel resources to the project, and the strategy of knowledge transfer withered.

At the local level, the challenge was to penetrate the primarily economic logic of building development and its regulation. Industrial pollution control had its own regulatory apparatus, linked to Environmental Impact Assessment and associated techniques for project-based environmental management (Wood, 1976). Factoring environmental considerations into the mainstream of city planning was a slow process. McHarg, Spirn and Douglas found decision-makers no more aware of atmospheric effects than they were of soils, hydrology, and the biosphere (Douglas, 1983; McHarg, 1971; Spirn, 1984). Environmental awareness was nudged by the sustainability principle in the Bruntland Report of 1987 (Blowers, 1993), but the planning agenda was being stretched in other directions too. In reaction against the modernist conception of city-making as an expert-led activity, the 1980s saw a turn towards participatory approaches that would give greater weight to community interests (Foreste, 1989; Healey, 1997). At another level the reaction against functionalism involved a fresh concern for historic fabric, and a revival of the visual and esthetic (but hardly ever atmospheric) dimensions of conventional streets and urban spaces (Orillard, 2014). The closing decades of the twentieth century saw a turn to neo-liberalism that tended to prioritise private property rights and constrain the scope for municipal action. In such a contested policy field it was never easy for the complex considerations of urban climatology to gain purchase. Summarizing the observed indifference to climatic variables in the planning process in Göteborg, Eliasson highlights the critical role of

communication with decision-makers (Eliasson, 2000). And since climatic knowledge is inherently spatial, she emphasizes the importance of *maps* – a point to which we return below.

Finally, the science was itself developing in directions ambivalent for knowledge transfer. The intellectual history of urban climatology can be traced in a continuous sequence of surveys of the state-of-the-art that commences with Kratzer and Brooks, continues through Chandler, Oke (repeatedly), Jáuregui and Roth up to Grimmond and beyond (Kratzer, 1937; Brooks, 1952; Oke, 1974–1989; Jáuregui, 1996; Roth, 2007; Souch and Grimmond, 2006). Arnfield's 2003 review of the previous two decades of urban climate research captures the turning-point (Arnfield, 2003). It shows how the discipline escaped the impasse of a monographic observation-based science that had hitherto described the urban effect in all its diversity but lacked means for comparison and generalization. The complex urban landscape was decomposed into simplified forms (such as cube-shaped buildings and street canyons) to facilitate systematic investigation. Following the lead of atmospheric sciences, researchers drew on mathematical physics to analyze the dynamics and energy balances within the urban atmosphere, the interplay between the solar cycle and anthropogenic fluxes, and consequences for human thermal sensations. The science base became more coherent, more transferrable between places and better linked to cognate specialisms such as hydrology, air quality, and environmental building design.

In the fullness of time this shift from place to process studies would yield immense dividends for applied urban climatology, allowing substitution of numerical simulation for laborious field observation campaigns, but the short-term implications for knowledge transfer were more ambiguous: research that allowed wider potential for scientific generalization offered less for *in situ* application. Understanding of process was not matched by work on application in the full variety of real-world contexts (Mills, 2006). Meteorological modeling, as explained in Baruch Givoni's *Climatic Considerations in Building and Urban Design*, had to be expressed in the tangible language of design choices (Givoni, 1998, p. 250).

A contrast could be drawn between the lagging application of urban climatology and the steady advance of applied technology in the fields of passive and low energy architecture, and heating and ventilation engineering (Taesler, 1991). Using the ludic analogy in William Lowry's brilliant teaching text, *Atmospheric Ecology for Designers and Planners* (Lowry, 1988) it was at the scale of individual project location and design that climate science could become a player in the game of design: for example through techniques such as the solar envelope concept developed by Ralph Knowles (Knowles, 1981, 2003), or the three-dimensional contribution of urban digital elevation models (DEMs) (Morello and Ratti, 2009). There was less chance of participation at the wider scales of the neighborhood or urban settlement. Planners rarely considered the aggregate effects of urban form upon solar potential and energy management (Futcher and Mills, 2013; Thomas, 2003). In a context of economic growth and plentiful carbon fuel, the consequences of climatic apathy could be ignored, in Len Warshaw's words, 'by simply countering or supplanting them with massive doses of energy expended as heating, cooling, ventilation, lighting and so on' (Warshaw, 1984, p. 23). The climatic dimension was allowed to remain a non-issue of the kind described by Matthew Crenson in his classic 1971 study of environmental indifference in the steel town of Gary Indiana, *The Unpolitics of Air Pollution: a study of non-decision-making in cities* (Crenson, 1971).

Urban climate management remained on the agenda only where it was supported by the political culture and active participation of the research community. Israel was one such center of activity. Work on climate and settlement originated with the Government Meteorological Service of the British Mandate, prior to the formation of the modern state (Wittkower, 1984). It gained salience in the massive programme of Jewish immigration after 1948, much of it from temperate zones. A strong academic tradition of microclimatic research supported the challenges of development in the hot Levantine climate (Bitan and Potchter, 1995; Erell, 2008). Arie Bitan advised the Israeli army on the design of bases and was commissioned by the Ministries of Energy and Transport to compile a *Climatic Planning Atlas of Israel for Physical and Environmental Planning and Design*, published by Tel Aviv University in 1991 (Bitan and Assif, 1984). However, its dense tabulation of times, seasons and wind directions, organized by climatic region, was an aid to design of specific projects rather than an urban planning reference. The thrust of Israeli work, as summarized by Erell and colleagues, was to apply



climatology at the architectural scale, for example by providing an empirical basis for climatic building regulation (Erell et al., 2003) or through optimal design of the spaces between buildings (Erell, 2011).

The pioneering applications at the urban scale emerged in German cities, where both the necessary and sufficient conditions were satisfied: an national meteorological service with an active interest in meso- and micro-climate, effective local government, an active research culture in the universities, and political acceptance of municipal regulation to achieve valued environmental ends (Schirmer, 1976, 1984; Weischet, 1980). Through this combination there emerged a methodology that matched the city plan in being map-based with documentary support: the *Klima atlas*.

#### 4. Demonstration

Each town has its own combination of synoptic conditions, topography, natural ecology and built form. Though the motions of air in an urbanized terrain are more complex and less intuitive than those of hydrological cycle, they do exhibit recurrent spatial patterns that can be mapped. Techniques of climate mapping originated in viticulture and were developed in the context of agricultural and forestry research – Rudolf Geiger saw the map as the synthesis of field-worker's long immersion in a landscape (Geiger, 1965). The application of climate maps by municipalities transformed the technique into a translation device – a methodology usable for public planning purposes.

A *Klima atlas* is not a weather chart but a pair of maps, the first of which plots the structure of the local climate in relation to characteristic land use areas or climatopes, while the second draws out policy recommendations. It displays only the repeating patterns of weather phenomena that have an impact on health, well-being or economic activity. The aim is not to optimize for a particular weather event, but to avoid harm, encourage flexibility for an uncertain energy future, and create variety of climates that will be serviceable in all seasons (Scherer et al., 1999). *Klima atlas* method seeks to give decision-makers – as Edward Ng puts it – an 'actionable understanding' of their air resource (Ng, 2011).

The pioneering work was done in Stuttgart, a manufacturing city in a valley location with low wind speeds, and consequent problems of air pollution. The city first established an Agency for Environmental Protection in 1938, including a municipal meteorologist to handle pollution-related aspects of its 1935 Urban Construction Bye-Law. During the Second World War the *Luftwaffe* exploited Stuttgart's topography, artificially generating fog to obscure from view the strategic concentration of manufacturing capacity along the valley floor. A chance side-effect was to reveal longitudinal airflow conditions as the fog dissipated, resulting in the identification of cold air drainage areas that came to be labelled as the city's fresh air swathes. The maintenance of these natural ventilators became a critical component of planning policy in Stuttgart, embodied in the city's post-war 1948 *General Binding Site Plan*. In 1953 the city adopted *Regulations for the Implementation of Functions in Climatology*, formalizing the policy contribution of scientific evidence on meteorological and noise abatement issues. Its in-house climatology unit published their first *Klima atlas* for Stuttgart in 1990, followed in 2008 by one for the wider metropolitan region. Earlier labor-intensive observational and mapping techniques were streamlined by numerical modeling of atmospheric processes, and GIS-based cartography. Formally incorporated into the planning process, the meso-scale climate analysis came to provide an evidence base for spatial planning (the *Flächenutzungsplan*), for detailed building codes (the *Baugeetzbuch*), for tall buildings policy (*Hochhäuser in Stuttgart*), for landscape design and green-space strategy; and for the city's medium-term strategies for carbon reduction and adaptation to global climate change (Hebbert and Webb, 2012).

Simplifying and rendering legible those aspects of the urban climate effect that are relevant to human health and comfort, the *Klima atlas* offers a means of communication between scientists and decision-makers. The use of a relatively high level of resolution allows point-specific recommendations for policy and regulation. On the 1st of January 1977, Germany's Federal Construction Law, now called the Federal Building Code, was revised to include air and climate in the list of factors that must be considered during the planning process. In 1993 the *Klima atlas* methodology was adopted as a German national standard by the Verein Deutscher Ingenieure (VDI-3787) *Environmental Meteorology, Climate and Air Pollution Maps for Cities and Regions*. With the encouragement of VDI 3787-1, the

approach was introduced in many other German cities, including Berlin, Dortmund, Dresden, Essen, Frankfurt, Freiburg, Heidelberg, Karlsruhe, Kassel, Leipzig, Mainz, Munich, and the joint regional planning board of the Ruhr Valley, the *Kommunalverband Ruhrgebiet* (KVR) (Ren et al., 2011).

## 5. Diffusion

Climate planning techniques developed in the context of a wealthy nation with exceptionally high environmental standards, deep-rooted cultural acceptance of environmental regulation, and willingness to fund major observational studies and maintain strong localized concentrations of scientific expertise. What of their transferability to different political and climatic contexts?

One early adopter was Japan, which had long-standing scientific links to German universities, as well as embedded cultural traditions of micro-climate awareness, for example in the use of pine hedges, *tsuji-matsu*, as windbreaks and sunshades. A seminal text was *Shôkiko* by Masatoshi Yoshino, first published in 1961 and translated into English as *Climate in a Small Area: an introduction to local meteorology* (Yoshino, 1975). Yoshino, still active in his nineties, met Rudolf Geiger in pre-war Munich and modeled his text on Geiger's but with stronger coverage of urban areas. His own most significant work related to the meso-scale climate of Tokyo, which he discovered to be a 'rain island' as well as a heat island in which summer sea breezes played an important role. Sea and land breezes became a major research focus of Japanese urban climatology, with consequent interest in how they could be managed. Already in the 1980s the *Klimaatlas* experiment was being disseminated through meetings of a bi-lateral German-Japanese seminar on urban climate. Several Japanese cities have commissioned their own climate atlases, including Fukuoka, Kobe, Osaka, Yokohama, and Tokyo Metropolitan Government, and work continues on refinement of mapping criteria (Kato and Hiyama, 2013).

From Japan the technique has spread to Hong Kong and mainland China, with widening interest in other hot-humid cities of south-east Asia, such as Singapore, Macao and Ho Chi Minh City. Tracking the diffusion, Ren, Ng and Katschner found applications in more than twenty countries (Ren et al., 2011). Building on these practical experiences, they have published the first Chinese text on applied urban climatology, with English translation to be published by Earthscan for an international readership (Ng and Ren, 2013). Within Europe, we find *Klimaatlas* technique being applied by the city of Lisbon, in collaboration with a team under the direction of Maria-João Alcoforado (Alcoforado et al., 2009). The present issue of this journal contains an account of a *Klimaatlas* for Bilbao, admittedly an advisory scientific study not adopted as policy by the municipality (Acero et al., 2013). Some of the most promising collaborative examples are from Dutch cities. Until recently Germany's western neighbor had no work of this kind, relying on the natural balances of a temperate maritime region, but relatively high rates of excess mortality during the 2003 and 2006 heat-waves prompted interest in techniques to manage UHI intensity (Van Hove et al., 2011; Kleerekoper et al., 2012). Sanda Lenzholzer has published the first Dutch-language text on applied urban climatology (Lenzholzer, 2013), and a well-publicized *Klimaatlas* project in Arnhem is interesting both for its methodological innovation – for example the use of bicycle-mounted meteorological stations for rapid and flexible data-collection – and for the internationalism of a project team which included participants from the Chinese University of Hong Kong, Cambridge, UK and Kassel, Germany alongside Utrecht and Wageningen (Ren et al., 2012).

There is no single, tight definition of a *Klimaatlas*. The VDI methodology has not been consistently applied even in Germany and many international experiments use different terminology. Spatial representations that combine atmospheric analysis with morphological and land-use information can be found under several other names, such as Urban Climate Maps (UCMaps), Urban Environmental Climate Maps (UECM), Urban Climate System (UCS), Air Ventilation Assessment System (AVAS), or Local Climate Zones (LCZ), the last being a means of mapping and evaluating urban temperature effects at neighborhood scale. Taken such techniques together, ICUC8 offered examples of science translation for the benefit of lay decision-makers in locations as diverse as Arizona, Bragança, Bilbao, Colombo, Curitiba, cities of South China, Dublin, Graz, the Great Lakes Region, Ho Chi Minh City, Hong Kong, Nagpur, Manchester, Nancy, Osaka, Phoenix, Quebec City, Shanghai, and Vancouver.



The variety of method reflects diversity in local climatic conditions, availability of data and expertise, and institutional differences in the focus and source of funding of the authority (e.g. air quality, flood control, heat stress, urban sprawl). Above all, translation into planning practice is determined by political culture. Regulation of property rights for environmental ends is taken for granted in some contexts but remains beyond the limits of political possibility in others. Depending on context, a climate map may be a public policy document with regulatory effect, an advisory analysis, a private sector negotiating tool or an advocacy document. But there is an underlying common factor in this wave of climate mapping – an intention to create a feedback loop from the urban atmosphere to the man-made environment in a medium legible to its makers.

## 6. Conclusion

In contrast to the disappointments of science-communication in the 1980s we find a current scene of active knowledge transfer as mayors, planners, developers and citizens embrace the adaptation and mitigation agendas posed to decision-makers world-wide by the climate science community via the Intergovernmental Panel on Climate Change: the double challenge of reducing their cities' carbon footprint, and preparation for the hazards of climate change. The topic is unambiguously flagged in report titles: the World Bank's *Cities and Climate Change – an Urgent Agenda*, UN-Habitat's *Cities and Climate Change* and *Climate Change and Cities* from the Urban Climate Change Research Network (World Bank, 2010; UN-Habitat, 2011; Rosenzweig et al., 2011).

As noted at the outset of this paper, urban-scale factors remain somewhat under-represented in the fresh wave of climate awareness (Hebbert and Janković, 2013). Reviewing the literature in 2007 Hunt and Watkiss noted the prevalence of sectoral assessments of vulnerability and impacts, a bias that has continued (Hunt and Watkiss, 2011). Examples of applied urban climatology are missing from several good practice guides. UN-Habitat's 2013 practically-oriented report *Developing Local Climate Change Plans* is a case in point (UN-Habitat, 2013). The introduction to data-sources lists IPCC assessment reports, 'scientific publications', 'the world wide web', and 'government departments', but techniques of UHI scale observation and data collection, modeling and mapping are not mentioned. The authors assume that climatic data will be downscaled from synoptic forecasts and warn that urban-scale climate predictions

'can only serve as indicators of what may take place. Even where relatively in-depth scientific surveys have been conducted for individual cities...they fall short of supporting detailed planning' (UN-Habitat, 2013, p. 46)

This paper has tried to apply the corrective of a historical narrative of efforts to link in-depth scientific surveys to detailed planning. We have seen how UN-Habitat itself played a formative role in those efforts at its Vancouver foundation conference in June 1976. The official German contribution to that event was a documentary film *Urban Development and Urban Climate*, presented with voice-over in Chinese, Russian, Japanese and English, showing Stuttgart's climate management in action. Then, its methods required the special resources of a rich municipality, and a climate-aware policy context difficult to replicate elsewhere.

Today those constraints are less applicable, and the pioneering work of German cities can be seen as a pilot phase allowing the refinement of a technique of wide potential. Key innovations have been the inclusion of bioclimatic considerations and the use of physiologically equivalent temperature (PET) measures; the switch to a GIS platform, allowing multiple data overlays and spatial analysis at ever more precise levels of resolution (meshes as tight as 70 or 50 meters); the development of low-cost lightweight meteorological equipment and radio-based data-collection; the coupling of remote sensing data and automatic classification software; the successful transfer of computational fluid dynamic (CFD) techniques from original engineering of small-scale fluid flows application to modeling of out-door atmospheres; accessible freeware such as the EnviMet programme developed by Michael Bruse of the University of Mainz; and international effort to agree of assessment procedures for climatopes and ventilation criteria which form the basis of planning guidelines (Fehrenbach et al., 2001). These developments take city planning from the static concept of climatic maps to a predictive

basis for scenario testing, evaluating of design alternatives and defensible regulation and policy, tailored to climatic context.

So the argument of this paper leads to a nuanced conclusion. Urban climatology as a branch of climate science is clearly not in its infancy. The field is more than mature, finding itself at the cutting edge of observation and modeling as synoptic weather science gets to grips with the long neglected urban anomaly. But the translation of science into technique shows a more mixed picture. On the one hand we have several decades of experience with *Klimaatlas*-type methods: on the other hand these techniques are only now starting their pathway of diffusion through cities worldwide. There are some unresolved questions concerning policy transferability and there is still a lack of evidence-based evaluation of their efficacy. The ‘urban climatology’ entry in the 2005 Springer *Encyclopedia of World Climatology* concluded that ‘the application of research findings of urban climatology on building design and urban environmental planning is beginning to emerge but is not yet widespread’ (Brazel and Qattrochi, 2005). Ten years on it would be hard to disagree with that verdict.

In this sense, *New Scientist* is right. Applied urban climatology is still in its early stages. But it’s an infancy of promise as cities begin to discover the potential value of urban-scale climatic management in the turbulence of global climate change. Unlike ice-water popsicles in Ulan Batur or revolving solar curtains in Abu Dhabi, the techniques described here do not require sophisticated engineering intervention. Their efficacy depends upon understanding the everyday fabric of the city in its natural setting. As Albert Kratzer urged more than half a century ago, every city should have this self-understanding in order to become a conscious ‘co-patterner’ of its own climate.

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