HEAT WAVES AND HEALTH: GUIDANCE ON WARNING SYSTEM DEVELOPMENT

THE WORLD METEOROLOGICAL ORGANIZATION

AND

THE WORLD HEALTH ORGANIZATION

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FOREWORD

To be signed by the Secretary-General of WMO and the Director-General of WHO

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PREFACE

Heat or anomalously hot weather that lasts for several days, often codified as "heat waves", has a clear impact on society including a rise in mortality and morbidity. Heat waves also place an increased strain on infrastructure (power, water and transport). Clothes and food retailing, tourism and ecosystem services can also be affected. In some instances heat waves may even trigger social disturbance at a number of levels. The impact of the heat waves is immense and sometimes catastrophic as manifested by the large number of heat-related deaths recorded across Europe in the summer of 2003. While the effects of heat may be exacerbated in cities, due to the heat island effect, the livelihoods and social well-being of non-urban communities can also be severely disrupted during and following periods of unusually hot weather.

Since the early 1990s, there has been recognition that heat and its associated impacts should not be treated as an inevitability of a varying or changing climate. Further the principles of risk assessment and management are being increasingly applied to a number climate hazards, with the intent of impact mitigation. Consequently and in accordance with the general paradigm of early warning systems, heat/health warning systems (HHWS) have been developed for a number of locations. The purpose of HHWS is to alert decision-makers and the general public of impending dangerous hot weather, and to serve as a source of advice on how to avoid negative health outcomes associated with hot weather extremes.

Since the implementation of the inaugural HHWS in the city of Philadelphia, USA in 1995, a large amount of international experience has accumulated regarding the development of HHWS. To date, however, this information has not been brought together in a single volume.

The purpose of this Guidance is to outline for NMHSs and health services the issues surrounding the general heat-health problem and present how an understanding of the biometeorology, epidemiology, public health and risk communication aspects of heat as a hazard can be used to inform the development of HHWS. The Guidance places emphasis on the practical aspects of HHWS at a generic level and is not intended to be prescriptive.

An explicit hope is that the Guidance will act as a catalyst for bringing together key players in NMHSs and health services for the purpose of initiating action concerning the management of heat as a hazard.

The Guidance has been produced to have global applicability and has drawn on expert opinion and learnt experience of a wide range of people and institutions involved in the development of warning systems and heat plans. In particular the Guidance has been informed by information contained in the US Environment Protection Agency's *Excessive Heat Events Guidebook* and the European Commission Framework V and VI funded projects *PHEWE*, *cCASHh* and *EuroHeat*.

Specifically the Guidance helps identifying the population at risk to heat exposure outlines approaches to assessing heat stress, presents the science and methodologies associated with the development of HHWS, overviews heat intervention strategies which are a necessary part of any truly integrated HHWS, considers the problem of communicating heat risk and how to evaluate HHWS and draws attention to the essential elements of summer heat plans within which HHWS are located. Longer term initiatives for managing heat as a hazard are presented at the end of the Guidance.

Readers are encouraged to read this Guidance alongside the WHO publication "Heat/Health Action Plans". We hope that the Guidance will be useful to decision makers around the world in National Meteorological Services, to the agencies that deal with the health effects of heat on people, to the emergency response and hazards communities, to the media, as well as to ordinary people whose circumstances make heat and heat waves an issue to be dealt with.

G. McGregor, P. Bessemoulin, K. Ebi and B. Menne
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EXECUTIVE SUMMARY

Heat waves are a pervasive natural hazard. Although there is no universally accepted definition of heat waves these are understood to be periods of unusually hot dry or hot humid weather that have an insidious onset and cessation, a duration of at least 2-3 days with a discernible impact on human and natural systems as demonstrated clearly by a number of devastating heat wave events over the last decade. Heat waves are relative to a location's climate; the same meteorological conditions can constitute a heat wave in one place but not another. Daytime and night time conditions are equally important in terms of understanding the health effects of heat waves which may range from heat rash, through heat cramps, to heat exhaustion, heat stroke and death. At the individual level, poor thermoregulation or the inability to balance heat gains to and heat-losses from the body is always at the heart of heat-related deaths.

In addition to thermoregulatory factors personal circumstances may well determine an individual's levels of heat risk. Such circumstances are often referred to as demographic and socio-economic risk factors. These include age (being elderly or very young), having pre-existing disease, living alone, being socially isolated or homeless, not having access to heat-health information in a variety of forms, being immobile, suffering from mental illness or not being able to undertake self-care. Other factors such as deprivation and gender may also be important. People possessing multiple risk factors are at high risk to heat.

One way to manage the risk of heat-related health-effects is through the development of heat/health warning systems (HHWS). The overall aim of an HHWS is to alert decision-makers and the general public of impending dangerous hot weather, and to serve as a source of advice on how to avoid negative health outcomes associated with hot weather extremes. Typically HHWS are composed of a number of elements which include weather forecasting, a method for assessing how future weather patterns may play out in terms of a range of health outcomes, determination of heat stress thresholds for action, a system of graded alerts/actions for communication to the general population or specific target groups about a pending period of heat and its intensity and to government agencies about the possible severity of health impacts.

HHWS are often part of a wider Heat Plan, which not only embraces the HHWS itself, but also considers as part of its remit general public education and awareness raising about heat, preparedness in terms of specific training of stakeholders in and responders to periods of extreme heat, specific guidance on actions to take to reduce personal levels of heat risk, clear guidance on heat risk governance and responsibility for the implementation of a range of strategies and the maintenance of critical hard and soft infrastructure (e.g. air conditioning in care homes and social/support networks), a plan outlining "the when, what, how and to whom" in relation to heat-related messages, a programme of evaluation in terms of whether the HHWS and Heat Plan are achieving their aims, a real time health surveillance system and advice on longer term strategies for reducing heat risk such as through climate sensitive building and urban design and town planning. HHWS are frequently developed at the local/regional level because data availability, human and technical resources and heat/health associations are usually geographically specific. For this reason the structure of HHWS varies significantly between cities, regions and countries.

Of principle concern in a HHWS is how to assess the level of heat stress, translate this into an estimate of a likely health outcome and to identify a critical heat stress threshold for a graded plan of action. A range of "simple" biometeorological indices and more "complex" human heat budget models exist for the assessment of heat stress, the choice of which will depend very much on the resources available to a NHMS. While most HHWS use either single meteorological variable such as maximum temperature, or simple biometeorological indices such as the Heat Index or the Apparent Temperature, some HHWS use outputs from numerical human heat budget models and air mass based synoptic climatological approaches for assessing heat stress. Similarly there are a number of climatological and epidemiological methods for determining action threshold points. Usually HHWS thresholds are response-specific, that is, the threshold values are set at a level associated with a negative human response as indicated by the long-term relationship between some measure of heat stress (e.g. the Heat Index) and mortality.

In HHWS based on a "simple index" of heat stress the threshold for action is usually the index value at which mortality (or any other health outcome) starts to rise rapidly with the type of action or level of alert being determined by the intensity and duration of the period of exceptional heat. In synoptic based HHWS the threshold for action relates to the occurrence of an air mass type known to be associated with anomalous levels of mortality. In the absence of health data, HHWS developers assume that extreme heat stress index values, associated with the 95^{th} to 99^{th} percentile, will precipitate a health response and thus use such values for identification of action thresholds.

Without an effective communication and dissemination strategy all energy and resources expended on the development of the "scientific" aspects of HHWS will be in vain. It is imperative that the risk associated with an impending period of anomalous heat is communicated precisely and adjusted according to the target group. Consequently bespoke messages, which may be action threshold specific (e.g. health authority, emergency service, media, and community action group) composed of clear unambiguous language, are an essential element of any HHWS. The same principles extend to the communication and outreach elements associated with wider Heat Plans.

Where HHWS are a fully integrated component of a Heat Plan, outputs from a HHWS are used to operationalise a set of heat intervention strategies from the individual to societal level. These range from simple actions at the personal level such as ensuring sufficient indoor ventilation and liquid intake to the initiation of community based buddy systems and the transport of the vulnerable to dedicated cooling centres. While there are a wide range of interventions, the local context, including human and financial resources, cultural practices, and other factors, will determine which interventions are most likely to be effective, and how the information is best communicated.

In order to gauge the effectiveness of a HHWS and identify opportunities for improvement it is necessary that HHWS developers, stakeholders and users critically reflect on system performance. Undertaking a formal programme of evaluation can assist such reflection. Identification of the objectives and methods of evaluation and who should be involved in evaluation should be an integral part of the early development phase of a HHWS. Although evaluations fall into two broad types, namely process and outcome based, within these broad categories there are many types of evaluation. Further when an undertaking evaluation it should be acknowledged that different stakeholders may have different requirements for the evaluation of a system.

HHWS operation and their associated heat-health threshold driven actions are season and event specific respectively. However actions beyond the seasonal and event levels dedicated to education, seasonal awareness and the development and testing of workable intervention strategies are important. In short, although the level of activity associated with HHWS operation during the season of heat will be high; a base level of activity associated with a wider Heat Plan needs to be sustained all year round for reasons of HHWS efficacy and social acceptability.

HHWS are dynamic and continually evolving in their level of sophistication. With rapid improvements in seasonal forecasting skill and the understanding of uncertainty associated with climate forecasts over the 10 – 90 day timeframe, opportunities exist for incorporation of long lead climate information, of a probabilistic nature, into HHWS.

In some locations the synergistic effects of heat and poor air quality are likely to contribute to the demise of some members of the population. Therefore there will always be a need to assess whether air quality information needs to be integrated into HHWS and if so how effective integrated climate, air quality and human health observation networks can be commissioned.

HHWS are just one aspect of the adaptive management of heat risk and should be considered alongside longer term heat management strategies especially in burgeoning mega-cities where the heat island effect is likely to result in added heat load. In this respect climate sensitive building and urban design and city planning has a role to play in hedging against future possible increases in severe heat events associated with climate change.

1. INTRODUCTION

1.1 Heat Waves: Their Physical Characteristics

Heat waves are a pervasive natural hazard that can exact a heavy toll on human systems affecting health, livelihoods and infrastructure. Natural systems can also be severely affected with the impacts sustained beyond the duration of the heat wave. Although there is no universally accepted definition of heat waves, these are understood to be periods of unusually hot dry or hot humid weather that have an insidious onset and cessation, a duration of at least 2-3 days and a discernible impact on human activities. During such periods of hot weather not only do daytime temperatures reach high values, but nocturnal temperatures and humidity levels may also rise well beyond their long-term mean. Heat waves are relative to a location's climate; the same meteorological conditions can constitute a heat wave in one place but not in another. Similarly at the level of the individual, the health effects of heat are relative due to a range of risk factors.

Meteorologically dry heat waves are often associated with stable periods of weather that bring clear skies and large inputs of solar radiation. Hot and dry conditions may also be accompanied by windy conditions, which can increase stress at excessive heat levels. Dry heat waves usually occur in locations with a continental or Mediterranean climate or where air is adiabatically warmed. Moist heat waves are characterised by very warm oppressive humid conditions throughout the day and night often with nocturnal cloud cover, a feature that prevents loss of heat accumulated throughout the day and thus little night-time relief. Such heat waves are often a feature of mid-latitude temperate and maritime climates. Based on these characteristics heat waves are more likely to occur in locations that possess a highly variable summer climate or a clear hot season (Figure 1). However locations without these characteristics are not immune from heat waves. On occasions, unusual combinations or ocean, land and atmospheric conditions may provide the climatological context for short-term climate surprises and thus the occurrence of extreme temperature and humidity events. The timing of heat wave events may also be partly related to the general climate setting. For example disastrous heat wave events in the region of southern Asia (Figure 1.1) appear to occur early in the summer before the arrival of the summer monsoon (Table 1).

Unlike many climate hazards, such as hurricanes, tornadoes, thunderstorm and floods, heat waves are geographically diffuse and occur over large areas. However, the effects of periods of anomalously hot weather may be exacerbated in large urban areas because of the local heat island effect. Because of the heat island effect, which is a product of the storage of heat from the sun in the urban fabric during the day and its slow release back into the environment at night and the lack of cooling evaporation, urban nocturnal temperatures may be several degrees above that of regional temperatures during heat wave events (Figure 1.2). This has special implications not only for urban inhabitants, but also for urban biophysical systems.

1.2 Societal Impacts of Heat Waves

Heat waves can have significant direct and indirect impacts on society. It is only the vulnerable individuals or sectors of society that may experience the direct impacts of heat waves. Although the main factors of vulnerability may vary geographically, depending on the social, economic and political setting, there are some commonalities across countries in terms of heat risk factors including being elderly, having pre-existing cardio-vascular or respiratory disease, living alone, working outdoors or being involved in heavy labour indoors close to industrial heat sources. In some places gender, the nature of a person's dwelling, where they are temporally or permanently resident (in a hospital or care home), being urban and poor and having certain medical conditions such as diabetes, fluid/electrolyte disorders, and some neurological disorders may also play a role. As well as the elderly, adults and children may also be affected during heat waves with the latter usually suffering from classic heat disorders, where as the elderly usually succumb to heat due to cardio-respiratory causes. For some members of the population the synergistic effects of several heat risk factors may prove fatal.

An indicative list of heat wave impacts for the period 2000-2007 complied from EM-DAT: The OFDA/CRED International Disaster Database held at the Université Catholique de Louvain, Brussels, Belgium is presented in Table 1. This provides a clear indication that over the period 2000-2007 most subtropical to mid-latitude regions were not immune from the impacts of heat waves. Southern and eastern Asia, Europe and North America are particularly notable as "hot spots" of heat wave disasters. Over the period 1990-1999 significant heat wave events also occurred in these regions including Orissa, India in 1995 and 1998 resulting in an estimated 558 and 2541 deaths respectively, Pakistan in 1995 with an estimated death toll of 523 and Chicago, USA in 1995 with 670 deaths reported. Regions other than those noted above where heat waves with significant impacts in terms of death, injury or damage have also occurred since 1990 include Mexico in April 1990 (380 deaths) and Australia in 1993, 1994 and 1995 and 2009 with the 2009 heat wave event in south-eastern Australia resulting in excess of 300 deaths and causing widespread disruption.

Further to the direct effects, heat waves can burden health and emergency services and also increase strain on physical infrastructure (energy, water, transport). Hospital admissions increase during heat events although the level of increase may vary by heat wave intensity and by a socio-economic factor such as age. Increased demands for water and electricity may result in shortages and even blackouts. If crops and livestock are badly affected during heat wave events then issues related to food and livelihood security are likely to arise. Wider social impacts may include effects in sectors such as clothes and food retailing, ecosystem services tourism and security.

1.3 Climate Variability, Climate Change, Heat Waves and Adaptation

Climate variability is a well known characteristic of climate, and heat waves represent one facet of that variability. With climate change, climate variability and thus the occurrence of heat waves is likely to increase. Evidence is emerging from the analysis of long-term climate records of an increase in the frequency and duration of extreme temperature events. Further, climate change modelling studies using regional climate models indicate that summers such as that experienced across Europe in 2003, which had disastrous consequences, may well be representative of what the future holds for European society come the latter part of the 21st century. In general not only is society faced with coping with current climate variability but also with finding ways to adapt to a changing heat wave climate.

In adapting to new heat wave futures, a range of options from the short through medium to long-term should be considered. Amongst a range of possible adaptations is the development of heat/health warning systems, the focus of this volume. The implementation of these, which are based on 3 to 10 day forecasts of unusually hot and stressful weather, along with an effective set of intervention strategies is one way in which society can address the challenges posed by heat waves and a changing heat wave climate.

The purpose of these guidance notes is to outline the factors associated with vulnerability to heat, describe the approaches to developing and assessing the effectiveness of a heat/health warning system, to sketch out a range of possible intervention measures and summarize the essentials for effective communication of the risk of heat-related health effects and associated coping strategies. In doing so, this set of guidance notes offers practical guidance to NHMS and health services on how to initiate the development of heat/health warning systems and help build capacity in meteorological and health services for planning for extreme hot weather events.

Table 1 Heat Wave Events as Reported in EM-DAT* by Region 2000 – 2007

Region	Country	Date	Killed	Injured	Damage (US$)
North Africa	Algeria	July 2003	40		
	Morocco	August 2003			809,000,000
East Africa	NA				
West Africa	Nigeria	June 2002	60		
Middle Africa	NA				
Southern Africa	NA				
North America	USA	July-August 2006	24		
	USA	July-August 2006	164		
	USA	July 2005	33		
	USA	June 2002	14		
	USA	August 2001	56		
	USA	July 2000	35		
Central America	NA				
South America	NA				
Caribbean	NA				
East Asia	China	May-Sept 2006	134		2,900,000,000
	China	July 2005		200	
	China	July 2004	39		
	China	July 2002	7	3500	
	Japan	July 2004	10	300	
Southern Asia	Bangladesh	July 2005			
	Bangladesh	May-June 2003	62		
	India	May 2006	47		
	India	June 2005	329		
	India	May-June 2003	1210		4,000,000,000
	India	May 2002	1030		
	India	April 2000	7		
	Pakistan	May 2006	84	100	
	Pakistan	June 2005	106	200	
	Pakistan	May-June 2003	200		
	Pakistan	May 2002	113	24	
	Pakistan	June 2000	24		
Central Asia	NA				
Western Asia	Cyprus	July 2000	5	400	
	Israel	July 2000			
	Jordan	July 2000		12	
	Turkey	July 2000	15	300	
Eastern Europe	Bulgaria	June-July 2000	7		
	Romania	June-July 2006	26	200	
	Romania	July-August 2005	13	500	
	Romania	July 2004	27		
	Russia	July 2001	276		
	Slovakia	July-August 2003			150, 000,000
	Czech Rep	July 2003	418		
	Hungary	July 2007	500		

Region	Country	Date	Killed	Injured	Damage (US$)
Northern Europe	UK	August 2003	2045		
Southern Europe	Albania	July 2004	3		
	Albania	July 2007	150		
	Canary Islands	July 2004	13	113	
	Croatia	July 2000	40	200	240,000,000
	Croatia	July 2007	788		
	Greece	July 2000	27	176	
	Italy	July-August 2003	20089		4,400,000,000
	Italy	June 2007	6		
	Macedonia	July 2004	15		
	Portugal	July 2006	41		
	Portugal	August 2003	2096		
	Serbia-Montenegro	July 2000	3	70	
	Slovenia	August 2003	289		80,000,000
	Spain	July 2006	21		
	Spain	July 2004	26		
	Spain	August 2003	15090	20	880,000,000
Western Europe	Austria	July-August 2003	345		280,000,000
	Belgium	July 2006	940		
	Belgium	August 2003	1175		
	France	July 2006	9		
	France	August 2004	19490		
	France	July 2006	1388		
	Luxembourg	July 2003	170		
	Switzerland	July 2003	1039		
	Germany	July 2006	2		
	Germany	August 2003	9355		
	Netherlands	July 2006	1000		
	Netherlands	August 2003	1200		
New Zealand and Australia	NA				
Melanesia	NA				
Micronesia	NA				

*Compiled from: "EM-DAT: The OFDA/CRED International Disaster Database - www.em-dat.net - Université Catholique de Louvain - Brussels – Belgium

2. THERMOPHYSIOLOGY AND HEAT RISK FACTORS

Heat waves are an emerging public health problem because of the interaction between changing climate, demographic and socio-economic conditions. A number of major heat wave events have occurred over the past decade some of which have had devastating effects.This chapter aims to review the physiology of heat (thermophysiology), the health impacts of hot weather and heat-waves and summarises some of the risk factors that contribute to the sensitivity to heat. Heat exposure factors and preventive interventions considered crucial for reducing mortality and morbidity and implemented before and during heat events will be outlined in Chapters 3 and 6 respectively.

2.1 Thermophysiology

For human beings it is crucial to keep the body core temperature at a constant within a narrow range of approximately 36.3 to 37.1 °C in order to ensure functioning of the inner organs and of the brain thus optimising comfort, performance and health. In contrast the temperature of the skin and extremities can vary strongly depending on the environmental conditions, which is one of the adaptation mechanisms to keep heat production and heat loss, at least over a longer period (“steady-state”), in equilibrium. Heat is generated by metabolic processes such as the breakdown of food as well as a result of physical activity, for example running. Sometimes if the heat produced is not sufficient shivering helps to increase it. In the case of surplus heat this must be released to the environment.

The body exchanges heat by convection (sensible heat flux), conduction (contact with solids), evaporation (latent heat flux), radiation (long- and short-wave), and respiration (latent and sensible). For the heat exchange process to be efficient strong temperature and humidity gradients must exist between the skin surface and the atmospheric environment. During a heat wave when the surrounding temperature is greater than the skin temperature (32-33 °C), the only mechanism for the dissipation of heat is evaporation. When sweat evaporates from the body surface, 0.58Kcal of heat is eliminated for each gram or millilitre of water that evaporates (Knochel and Reed, 1994; Guyton and Hall, 2000). At maximum efficiency in a dry environment, sweating can dissipate about 600 Kcal/hour for an unacclimatized person (Knochel and Reed, 1994; Guyton and Hall, 2000; Bouchama and Knochel, 2002). On the other hand, when ambient humidity is elevated, this mechanism becomes less effective. Evaporation also becomes less effective when there is reduced wind, or if air circulation is hampered by, for example, tight-fitting clothes, which prevents saturated air being carried away from the skin. One way of understanding the exchange of heat between the body and the surrounding environment is through a consideration of the heat budget (section 3.2 and 3.3).

The human organism can be separated into two interacting systems of thermoregulation: (1) the active control system which includes the thermoregulatory responses of shivering thermo-genesis, sweat moisture excretion, and peripheral blood flow (cutaneous vasomotion) (Fig. 2.1) and (2) the passive control system dealing with the physical human body and the heat transfer phenomena occurring in it and at its surface (Fig. 2.2). These account for local heat losses from body parts by free and forced convection, long-wave radiation exchange with surrounding surfaces, solar irradiation, and evaporation of moisture from the skin and heat and mass transfer through non-uniform clothing. Under comfort conditions the active system shows the lowest activity level indicating no strain. Increasing discomfort is associated with increasing strain and accordingly impacts on the cardiovascular and respiratory systems.

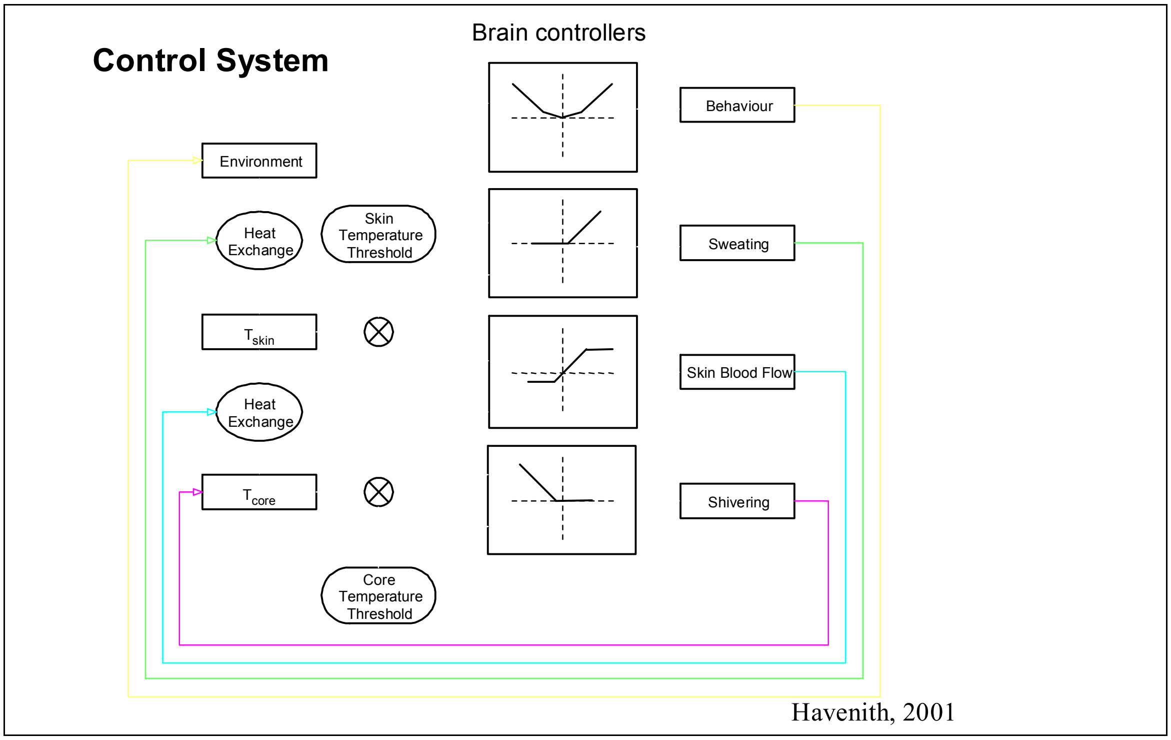

Figure 2.1 The control system (Fiala et al. 2001)

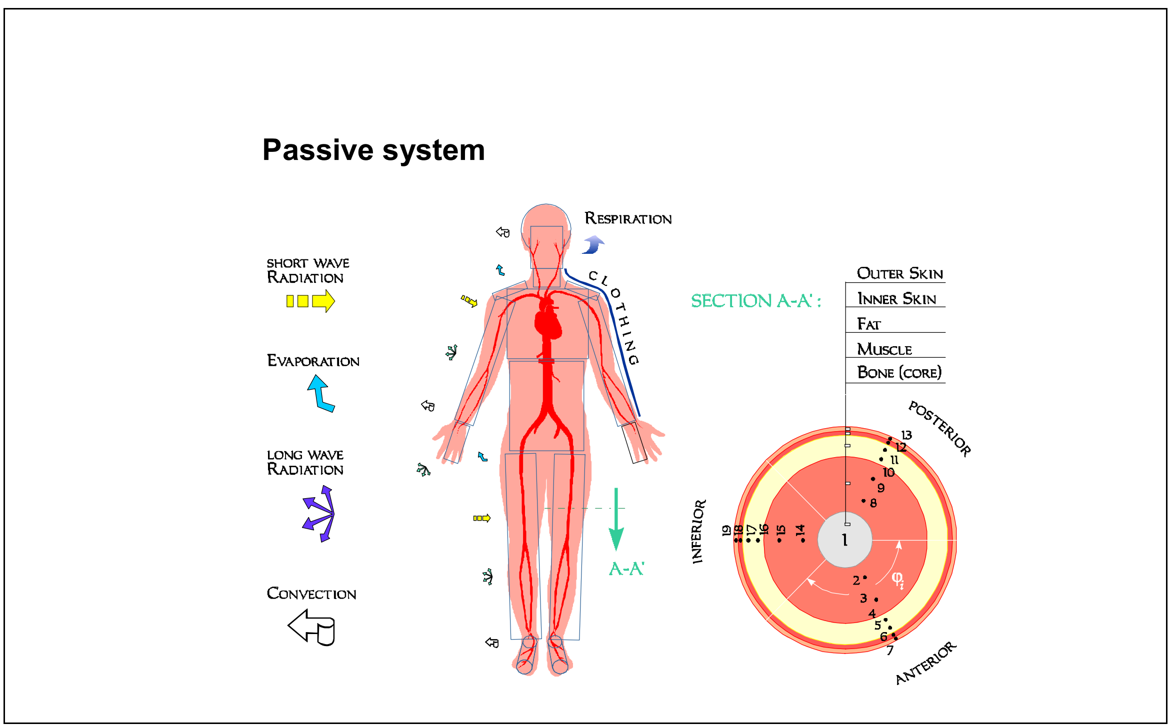

Figure 2.2 The passive system (Fiala et al. 2001)

When heat exchange between the body and the atmosphere is hampered this produces strain. People with limited adaptation capacity, such as those who are not fit, can die from assorted causes. Poor thermoregulation is always at the heart of such heat-related deaths. Given this, ideally a health-related definition of thermal environmental stress (heat load) that is thermo-physiologically significant is required. However as outlined below, depending on resources and data availability, this may not be readily achievable in some circumstances.
The tolerance to thermal extremes depends on personal characteristics (Havenith, 2005) including age, fitness, gender, acclimatization, body shape and weight. Age and fitness are the most important and are often closely correlated. High age and/or low fitness means low cardiovascular reserve, which causes low thermal tolerance.

2.2 Heat Illness and deaths

Excessive heat can cause the development of heat stroke, heat exhaustion, heat cramps, heat edema and heat rash. It can cause severe dehydration, acute cerebrovascular accidents and contribute to thrombogenesis. It can further aggravate chronic pulmonary conditions, cardiac conditions, kidney disorders and psychiatric illness (see Table 2.1).

Table 2.1 Heat Illness

Medical condition	Signs and symptoms/ Mechanisms
Heat rash	Small red itchy papules appear on the face, neck, upper chest, under breast, groin and scrotum areas. This can affect any age but is prevalent in young children. Infection with Staphylococcus can occur. It is attributed to heavy sweating during hot and humid weather
Heat oedema	Oedema of the lower limbs, usually ankles, appears at the start of hot season. This is attributed to heat-induced peripheral vasodilatation and retention of water and salt.
Heat syncope	This involves brief loss of consciousness or orthostatic dizziness. Common in patients with cardiovascular disease or taking diuretics, before acclimatization takes place. It is attributed to dehydration, peripheral vasodilatation and decreased venous return resulting in reduced cardiac output.
Heat cramps	Painful muscular spasms occur, most often in the legs, arms or abdomen, usually at the end of sustained exercise. This can be attributed to dehydration, loss of electrolytes through heavy sweating and muscle fatigue.
Heat exhaustion	Symptoms include intense thirst, weakness, discomfort, anxiety, dizziness, fainting and headache. Core temperature may be normal, subnormal or slightly elevated (less than 40 ºC). Pulse is thready with postural hypotension and rapid shallow breathing. There is no mental status alteration. This can be attributed to water and/or salt depletion resulting from exposure to high environmental heat or strenuous physical exercise.
Heatstroke	Body temperature rapidly increases to greater than 40 ^{o}C and is associated with central nervous system abnormalities, such as stupor, confusion or coma. Hot dry skin, nausea, hypotension, tachycardia and tachypnoea are often present. Heatstroke results from exposure to a high ambient temperature (classic heatstroke) or secondary to vigorous physical activity (exertional heatstroke) overwhelming the heat dissipating mechanisms. Exaggeration of acute phase response and alteration of heat-shocks protein regulation have been recently suggested.

2.3 Factors that increase the risk of heat illness and deaths

Heat risk is the outcome of the product of individual or popular vulnerability to heat and the probability of the occurrence of a damaging heat event. Vulnerability to heat is often conceptualised as the interaction between exposure and sensitivity factors. The former usually relates to the physical environment while the latter refers to personal or population characteristics.

There are many factors which influence heat-related morbidity or mortality. They can be divided into those that affect population exposure anddemographic, socio-economic and individual factors which are often referred to as heat risk factors. Exposure factors will be addressed in chapter 3.

2.3.1 Behaviour

Behaviour has a principal effect on exposure, but may also affect sensitivity. People who overexert during work or exercise may become dehydrated and susceptible to heat sickness and deaths. Similarly, very young or very old people may be at increased risk due to inadequate fluid intake.

2.3.2 Socio-economic and demographic factors

The scientific evidence base for the social and demographic determinants of heat-related health effects is still limited. Studies from both Europe and North America differ in some of their outcomes. In both, the greatest effects of heat were in the elderly but effects are also apparent for adults and children. Aging decreases tolerance to heat (Anderson and Kenney, 1987; Knochel and Reed, 1994), thirst is sensed late due to its increased threshold, latency to trigger sweating, reduction in the number of sweat glands often co-morbid illness and multiple medications, as well as physical or cognitive impairment.

The effect of heat appears to be greater in women than in men in Europe and greater in men than in women in the US. However, the cause of this difference is not understood. Woman have higher core body temperatures and skin temperature and may be less tolerant of heat than men (Havenith, 2005). A study where men and woman were matched on physical characteristics (size, body fact, etc) found that the differences were minimal. There is also evidence of an adverse effect of menopause on thermoregulation during heat exposure, in addition to its effects on cardiovascular fitness (Burse, 1979). The effects of gender are age-specific. All countries in Europe show greater effects on women in the elderly age groups. However, for non-elderly mortality, the gender differences are less clear. In Portugal, there does not seem to be a clear gender pattern for excess mortality in age groups below 55 (Nogueira, 2005).

There are likely to be important social factors that explain differences in mortality patterns between men and women during heat waves. For example, in Paris, the heat risk increased for unmarried men, but not unmarried women, while being a foreign national benefited women but not men. It was also apparent that excess mortality was greater in single persons (that is, those not married or cohabiting) and this was most apparent for men. Two studies from France during the heat wave of 2003 report that the mortality of widowed, single and divorced subjects was greater than that of married people. This may indicate that individuals with less social support were more at risk. Four case-control studies reported that increased social contact was a protective factor. The effects of social isolation or the role of social networks in coping with hazards is not straightforward and requires further research (Kovats and Hajat, 2008). Hospital inpatients and nursing home residents are at higher risk to heat-related mortality despite being under the care of professionals.

There is some limited evidence that lower income groups in urban areas were more at risk of heat wave related mortality in the August 2003 European heat wave, but many studies also show that there is no modification of the temperature–mortality relationship by socioeconomic status. Therefore, it is not clear that poor urban populations are more at risk from heat-related mortality in Europe.

In the United States there is good evidence that people of lower socioeconomic status are at increased risk of heat death during a heat wave (Smoyer, 1998). Some European studies report no apparent effect of socioeconomic status. A study in Italian cities used level of education as an indicator as it is available on individual death certificates. Excess mortality in Rome during the summer of 2003 was 6% in persons with the highest level of education and 18% in persons with the lowest level of education, and a similar pattern was observed in Milan (Michelozzi et al., 2005).

A meta-analysis of case-control studies considering risk and protective factors for heat-wave mortality was performed in EuroHEAT(Bouchama et al., 2007) Table 2.2 illustrates the results and reveals that the highest risk factors are being confined to bed, pre-existing psychiatric conditions, not leaving home daily, unable to take adequate self-care and pre-existing cardiovascular conditions.

Table 2.2 Risk and protective factors for dying in a heat wave

Risk factor	Odds ratio (OR)	95% CI
Being confined to bed	6.44	4.5–9.2
Not leaving home daily	3.35	1.6–6.9
Unable to take adequate self-care	2.97	1.8–4.8
Pre-existing cardiovascular condition	2.48	1.3–4.8
Pre-existing pulmonary condition	1.61	1.2–2.1
Pre-existing psychiatric condition	3.61	1.3–9.8
Having working air conditioning at home	0.23	0.1–0.6
Visiting cool environments	0.34	0.2–0.5
Increasing social contact	0.40	0.2–0.8
Taking extra showers or baths	0.32	0.1–1.1
Use of electric fans	0.60	0.4–1.1
Source: Bouchama et al., 2007.		

2.3.3 Individual factors

Several behavioural and medical factors create risk for heat illness and deaths. These are illustrated in Figure 2.3.

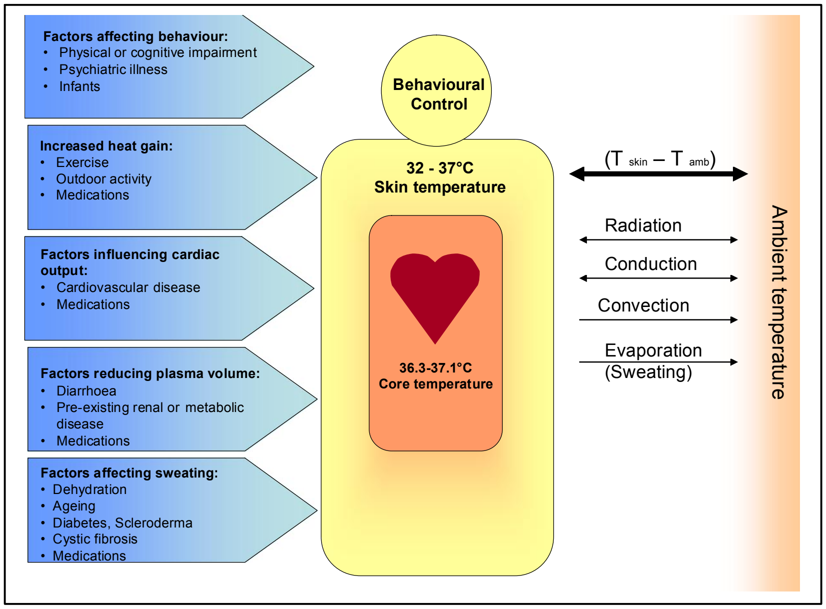

Figure 2.3 Medical and behavioural factors affecting human thermoregulation and the risk of heat illness (adapted from Bouchama, 2007)

When excessive heat exposure overwhelms the body's heat-dissipating mechanisms, core temperature rises. An increase of less than 1ºC is immediately detected by thermo-receptors disseminated throughout the skin, deep tissues and organs (Benzinger and 1969; Knochel and Reed, 1994; Guyton and Hall, 2000; Bouchama and Knochel, 2002). The thermo-receptors convey the information to the hypothalamic thermoregulatory centre, which triggers two powerful efferent responses to increase dissipation of heat; this takes the form of an active cutaneous vasodilatation by inhibiting the sympathetic centers that cause vasoconstriction and initiation of sweating through cholinergic pathways (Benzinger and 1969; Knochel and Reed, 1994; Guyton and Hall, 2000; Bouchama and Knochel, 2002). The cutaneous vasodilatation results in marked increases in blood flow to the skin and cardiac output, up to 8 and 20 litres /minute respectively, at the expense of other major vascular beds such as splanchnic beds (Rowell, 1983). These cardiovascular adjustments to accelerate the transport of heat from the core to the periphery for dissipation to the surroundings, constitute a major stress on the cardiovascular system.

Accordingly, thermoregulation during severe heat stress requires a healthy cardiovascular system. Initiation of sweating results in the production of up to 2 litres per hour of sweat rich in sodium and potassium (Knochel and Reed, 1994; Guyton and Hall, 2000). This is additional stress on the cardiovascular system if the plasma volume is not properly restored. These two responses are complemented by the activation of heat gain reduction mechanisms (Knochel and Reed, 1994; Guyton and Hall, 2000). These comprise the inhibition of shivering and the reduction of heat generated by cellular metabolism, and behavioral adjustment, i.e., adaptation (reduction) of the level of physical activity, the donning of appropriate clothes (light, loose-fitting), and the search for a cool environment.

Because a healthy cardiovascular system is essential for maintaining a normal body temperature during heat stress (Rowell, 1983) the inability to increase cardiac output because of cardiovascular disease or heart medications that depress the myocardium, will increase the susceptibility to heatstroke and/or cardiovascular failure and death (Kilbourne et al., 1982; Vassallo and Delaney, 1989; Semenza et al., 1996; Bretin et al., 2004).

Also, inability to dilate the cutaneous circulation and increase the skin blood flow because of peripheral vascular diseases e.g. diabetes, atherosclerosis or medications, e.g. sympathomimetics, increases the risk of severe heat illness (Knochel and Reed, 1994; Martinez et al., 2002). Cardiovascular death is a prevalent cause of death during heat waves. However, any chronic medical condition must be considered as a potential risk factor for heat-wave related injury and death, as demonstrated recurrently in epidemiological studies from Europe and North America (Table 2.3) (Kilbourne, 1999; Semenza et al., 1999; Hemon and Jougla, 2004; Michelozzi et al., 2005; Nogueira, 2005; Bretin et al., 2004).

Dehydration decreases plasma volume and venous return and thus cardiac output. It also slows the sweating rate (Knochel and Reed, 1994). This is a common cause of hyperthermia and death in both extremes of age, namely infants and children less than 4 years old and elderly or cognitively impaired persons, all of whom rely on adults to provide an adequate liquid intake (Knochel and Reed, 1994; Guyton and Hall, 2000). Factors that promote excessive fluid loss such as the presence of diarrhoea or febrile illness in the pediatric population, and pre-existing renal or metabolic disease and taking diuretics in the elderly, may increase the risk of heat-related injury and death (Knochel and Reed, 1994).

Increasing the volume and effective evaporation of sweat is the main mechanism for heat dissipation during a heat wave (Knochel and Reed, 1994; Guyton and Hall, 2000). Dehydration, drugs with anticholinergic properties, aging and chronic disease, such as diabetes, scleroderma, cystic fibrosis which affect the number and/or function of sweat glands, can considerably increase the risk of hyperthermia and heatstroke (Buchwald and Davis, 1967; Kilbourne et al., 1982; Knochel and Reed, 1994; Kritikou-Pliota et al., 2000; Martinez et al., 2002).

Clinical and physiological evidence indicates a range of conditions that increase the risk of heat stress in an individual. The epidemiological evidence for certain medical conditions as risk factors for mortality in heat waves is less clear, but a range of serious conditions could possibly increase the risk of heat-related mortality such as diabetes, fluid/electrolyte disorders and some neurological disorders (Table 2.3). However, findings from different countries are not very consistent and a wide range of chronic diseases are implicated in heat-related deaths, which is consistent with the limited information on the pathophysiology of heat.

Table 2.3 Chronic conditions that increase risk of heat mortality (epidemiological evidence)

Group	ICD-10 code
Diabetes mellitus, other endocrine disorders	E10–E14
Organic disorders mental disorders, dementia, Alzheimer's	F00–F09
Mental and behavioural disorders due to psychoactive substance use, alcoholism	F10–F19
Schizophrenia, schizotypal and delusional disorders	F20–F29
Extrapyramidal and movement disorders (e.g. Parkinson's disease)	G20–G26
Cardiovascular diseases, hypertension, coronary artery disease, heart conduction disorders	I00–I99
Diseases of the respiratory system, chronic lower respiratory disease (e.g. chronic obstructive pulmonary disease, bronchitis)	J00–J99
Diseases of the renal system, renal failure, kidney stones	N00–N39
Source: Kovats and Hajat, 2008.	

2.3.4 Acclimatization

This is an adaptive response to a hot environment in which an individual learns to tolerate exposure to excessive heat (Knochel and Reed, 1994; Guyton and Hall, 2000). This adaptation may take two to six weeks and includes physiologic adjustment of the cardiovascular, endocrine and renal systems. This results in increased maximal stroke volume, decreased maximal heart rate, expansion of plasma volume, and higher glomerular filtration rate and hence less tachycardia and work for the cardiac muscles. Also, sweating is initiated at a lower temperature and in greater volume, but with sodium chloride content reduced, resulting in more efficient heat dissipation and less salt depletion and dehydration (Knochel and Reed, 1994; Guyton and Hall, 2000; Bouchama and Knochel, 2002). High death rates associated with early season heat events may well be due to a lack of intra-seasonal acclimatisation, especially in the elderly.

2.3.5 Medication

Medications are frequently associated with the high morbidity and mortality observed during heat waves (Kilbourne et al., 1982; Kaiser et al., 2001; Bretin et al., July 2004). Medications can hinder the thermoregulatory and cardiovascular responses to excessive heat exposure and thereby precipitate hyperthermia and heatstroke (Goldfrank et al., 1979; Clark and Lipton, 1984; Vassallo and Delaney, 1989; Martinez et al., 2002). Medications can also aggravate the clinical manifestations of heat illness.

Many medications can increase the risk of heat illness by directly affecting the central and peripheral mechanisms of thermoregulation namely the thermoregulatory centre or afferent and efferent pathways, sweating, cutaneous vasodilatation and/or increase in cardiac output and thereby heat elimination (Ellis, 1976; Vassallo and Delaney, 1989; Martinez et al., 2002).

Medications of note are:

- Anticholinergics: these are present in several widely used medications such as antihistamine, antipsychotic, antispasmodic, antidepressant, and antiparkinson preparations (Hahn, 1975; Schwartz, 1976; Ducrot et al., 1979; Caldroney, 1981; Lefkowitz et al., 1983; Adubofour et al., 1996; Epstein et al., 1997; Martinez et al., 2002; Kerwin et al., 2004) and are potent inhibitors of sweating.

- Antipsychotics: in addition to their peripheral effects through the cholinergic pathway, they interfere with the thermoregulatory centre and afferent pathways to the hypothalamus, slowing efferent responses, namely cutaneous vasodilatation, and thereby reducing heat elimination. Both conventional (Haloperidol, chlorpromazine) and atypical antipsychotic medications (Clozapine) have been implicated in heat-related illness and death (Ducrot et al., 1979; Lefkowitz et al., 1983; Martinez et al., 2002; Kerwin et al., 2004; Kwok and Chan, 2005).

- Sympathomimetics: these increase heat production by increasing motor activity while reducing heat dissipation via peripheral vasoconstriction and decrease of cutaneous blood flow. Drugs with sympathomimetic effects include the over-the-counter nasal decongestants (ephedrine, pseudo-ephedrine, phenylephrine), appetite-suppressing drugs, amphetamines, and cocaine (Kew et al., 1982; Martinez et al., 2002; Kraemer et al., 2003).

- Nitrates and calcium channel blockers: these are used pharmacologically as a vasodilator, e.g. in angina pectoris or hypertension, and can theoretically precipitate hypotension in persons who tend to be dehydrated during excessive heat exposure, particularly the elderly.

Heat exposure can also increase medication toxicity and/or decrease its efficacy. Dehydration and changes in blood volume distribution associated with excessive heat exposure and the thermoregulatory response can influence drug levels, their kinetics and excretion and hence their pharmacological activity (Weihe, 1973). This may enhance their toxicity, especially those drugs with a narrow therapeutic index, such as digoxin or lithium. High ambient temperatures can affect adversely the efficacy of drugs, as most manufactured drugs are licensed for storage at temperatures up to 25°C(Crichton, 2004). This is particularly important for emergency drugs used by practitioners including antibiotics, adrenalins, analgesics and sedatives.

2.4 Summary

On a daily basis the human body works to stabilise its core temperature at around 37.5°C by attempting to balance heat gains and heat losses through a variety of thermophysiological means. When the body is unable to shed excess heat, heat illness may occur ranging from annoying heat rash through to possibly fatal heat stroke. Because a healthy cardiovascular system is essential for maintaining a normal body temperature during heat stress, the inability to increase cardiac output because of cardiovascular disease or medications that depress the myocardium or inhibit heat loss pathways, will increase the susceptibility of individuals to heatstroke and/or cardiovascular failure and death. In addition to thermoregulatory factors personal circumstances may well determine an individual's levels of heat risk. Such circumstances are often referred to as demographic and socio-economic risk factors. These include age (being elderly or very young), having pre-existing disease, living alone, being socially isolated or homeless, not having access to heat-health information in a variety of forms, being immobile, suffering from mental illness or not being able to undertake self-care. Other factors such as deprivation and gender may also be important. People possessing multiple risk factors are at high risk to heat.

3. ASSESSMENT OF HEAT STRESS

In the previous chapter, thermophysiology of heat and heat risk factors were described. Based on this it is clear that there is a close relationship between humans and the thermal component of the atmospheric environment. The purpose of this chapter is to focus upon the thermal environment and describe briefly the nature of heat waves, factors that influence exposure to heat and methods for assessing heat stress.

3.1 Heat waves

Although there is no general accepted definition of a heat wave (Souch and Grimmond, 2006; Robinson, 2001), heat waves can be considered as rare episodes with a sustained heat load that are known to affect human health (Kovats and Jendritzky, 2006). A heat wave definition applied to health should consider both the extreme weather event but also take into account the health outcome during heat episodes. There is usually an anomalous increase in mortality with increasing heat load rather than a sudden increase above a clear threshold. Heat intensity and duration, but also time within the year, repetition, time between adjacent events and acclimatization of individuals are important determinants of the health outcomes of heat waves. From a cause-effect related perspective, one approach to heat wave definition is that based on the physiological response (strain) to environmental stress in the form of exposure to heat as outlined in section 3.3.2.

3.2 Exposure

Exposure, in a strict sense, relates to proximity to the source of stress. In the case of heat warnings the heat source is quite diffused unless direct exposure, as would occur if standing directly in the sun, is experienced. Single meteorological variables, simple biometeorological indices or the output from human heat budget models (see section 3.4). These are based on information from first order weather stations (often at airports) or from climate stations in rural areas not explicitly established for weather and health purposes. Therefore when applying such data for defining heat exposure it must be borne in mind that (1) the urban heat island (UHI) effect may intensify the regional heat load and (2) there is usually no reliable information about the actual heat exposure of the population living indoors on different floors of buildings with different thermal characteristics. Thus the specific heat exposure of the population is unknown and both analyses and forecasts of heat load can only be considered an estimate.

The intensity, duration and timing of heat waves have been shown to influence the risk of mortality. In the EuroHEAT study both Tappmax and Tmin were associated with an increase in mortality and the impact of heat-waves characterized by longer duration was 1.5–5 times higher than for short heat-waves (Fig. 1). The heat-wave effect was stronger in the elderly. The highest increase was observed in Athens, Budapest, London, Rome and Valencia, in persons in the 75+ age group. In all cities, females were at higher risk than males. (Michelozzi et al., 2008).

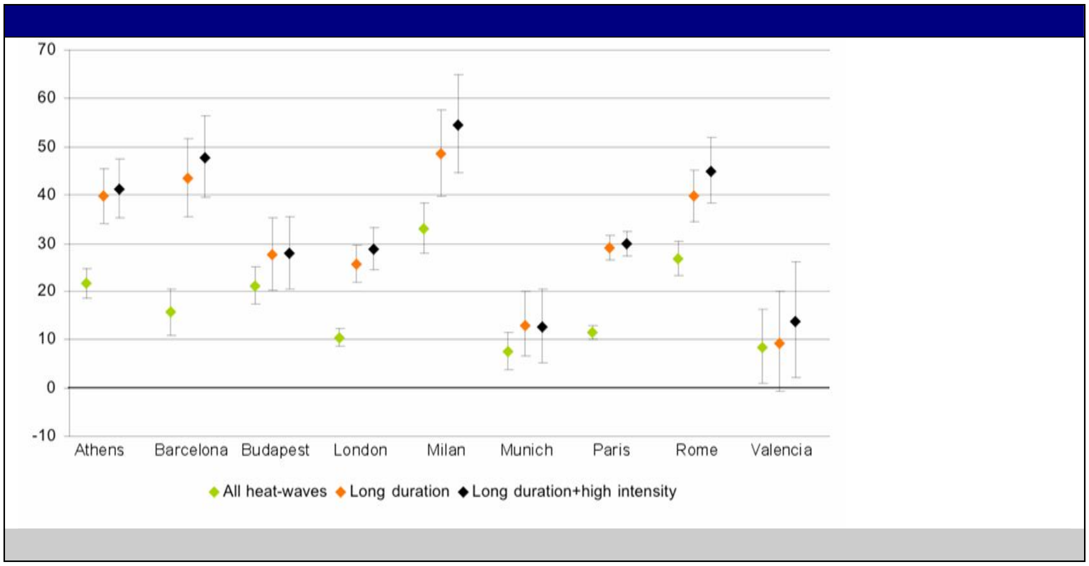

Figure 3.1 Effect of heat-waves with different characteristics on total mortality among people aged 65+ (% increase and 90% CI)
Source: Matthies et al. (2008)

Heat waves early in the summer (especially June) have been shown to be associated with greater impacts on mortality than heat waves of comparable or hotter temperatures in the same population (Hajat et al., 2002; Paldy et al., 2005). The impact of high temperatures later in the summer is sometimes diminished after an early heat wave. In the summer of 2003 in Germany, several heat episodes occurred even before the August event and the impact of the August heat wave was much higher than expected (approximately twice as much as the other six heat episodes together).

Urban areas

Only 0.2% of the earth's surface is covered with urban areas (Matzarakis, 2001), but 47% of the world population and 73% of the population of Europe live in urban areas (Deutsche Stiftung Weltbevölkerung, 2002).The number of people living in urban areas is rapidly growing in developing countries. By 2025, the population living in cities is likely to increase to 60% (Bitan, 2003). Temperatures are higher in urban areas.This is caused by many factors, including less radiant heat loss in the urban canopy layer, lower wind velocities and increased exposure to radiation (Jendritzky and Grätz, 1999). Local and regional climates are modified significantly by urbanization and other land-use changes. Urban climates are modified by changes in the water balance, the radiation and energy budget and changes in the wind-field (Gross, 1996). Global climate change will interact with other important factors (urban planning and construction of the builtUrban heat islands are a factor in many cities and refer to the temperature difference between that observed inside the city compared to that outside (Koppe et al., 2003).

Urban heat islands

Urban heat islands are a factor in many cities and refer to the temperature difference between that observed inside the city compared to that outside (Koppe et al., 2003). Heat islands have been shown to be of particular importance in some heat-wave events. During the 1995 Chicago heat-wave, when air temperatures reached 38°C (Kunkel et al., 1996), the impact of the heat-wave was exacerbated by the urban heat island effect, which raised night-time temperatures by a further 2°C. Within the city, it is difficult to identify "hot spots" where temperatures are particularly high. Heat islands are highly dynamic in time and space, and are therefore hard to quantify either spatially or temporally for individual heat-wave events. Although much is known about the factors of the built environment that increase temperatures, when estimating health effects within a city, confounding by housing type and socio-economic factors becomes very important. Heat-related mortality is not confined to urban areas, although the risks are larger in urban areas compared to rural areas. The reasons for the greater risk in urban areas may be both due to higher day and night time temperatures, but also differences in housing and other vulnerability factors.

Other things being equal, people living in cities are likely to be at higher risk than rural dwellers because of the urban heat island effect, but this issue has not been systematically studied. A vulnerability to impacts differs for urban and rural areas because of a heat island effect in the former that, for example, in Athens can amount up to 4.6°C in summer months. An excess mortality observed in France ranged from +4% in Lille to +142% in Paris, suggesting that either heat gain by city buildings or traffic patterns may influence it. As an exception, mortality impacts were more pronounced in rural villages than in provincial capitals in Spain. In August, 2003, it is clear that population in the northern part of France, away from the Atlantic coast,

Indoor thermal load

Most homes have an indoor temperature of between 17°C to 31°C. Humans cannot comfortably live in temperatures outside this range. There are three main factors that are associated with indoor heat exposures: the thermal capacity of buildings, the position of an apartment and the behaviour and ventilation. In France, in 2003, the risk of death was increased by living in buildings with few rooms, with poor insulation or with a larger number of windows. Living on upper floors, especially the top floor, or having the bedroom under the roof also increased the risk (Vandentorren et al., 2006).

3.3 Thermal Assessment Procedures

Because air temperature alone has not been considered as a good indicator of the human thermal environment or heat, thermal indices - most of them two-parameter indices - have been developed to describe the complex conditions of heat exchange between the human body and its thermal environment. For warm conditions, indices usually consist of combinations of dry bulb temperature and different measures for humidity. Comprehensive reviews of such *simple biometeorological indices* can be found in Fanger (1970), Landsberg (1972), Driscoll (1992), and Parsons (2003).
Without claim for completeness, a set of available and operationally applied thermal assessment procedures is reviewed below. These are presently being utilized by various national and local weather services around the world, and can be easily evaluated by the potential user, based on the need to describe thermoregulatory processes and heat load as described in chapter 2 and section 3.2.

3.3.1 Simplified biometeorological indices

3.3.1.1 Heat index

The Heat index (HI) is an index that combines air temperature and relative humidity to determine an apparent temperature — how hot it actually feels. When the relative humidity is high, the evaporation rate of water is reduced. This means heat is removed from the body at a lower rate, causing it to retain more heat than it would in dry air. HI is widely used in the USA and is effective when the temperature is greater than 80ºF (26ºC) and relative humidity is at least 40%.

The formula to calculate the Heat Index is:

Heat Index(HI) =

-42.379 + 2.04901523(Tf) + 10.14333127(RH) - 0.22475541(Tf)(RH) - 6.83783x10**(-3)*(Tf**(2)) - 5.481717x10**(-2)*(RH**(2)) + 1.22874x10**(-3)*(Tf**(2))*(RH) + 8.5282x10**(-4)*(Tf)*(RH**(2)) -1.99x10**(-6)*(Tf**(2))*(RH**(2)) Eq. 1

Where Tf = air temperature in degrees Fahrenheit, RH= relative humidity expressed as a whole number. (for conversion: Tc = (Tf – 32) * 5 / 9)

3.3.1.2 Humidex

The humidex is a Canadian innovation, first used in 1965. It was devised by Canadian meteorologists to describe how hot humid weather feels to the average person (Smoyer-Tomic et al, 2003). The humidex combines the temperature and humidity into one number to reflect the perceived temperature.

Humidex = (air temperature) + h Eq. 2

h = (0.5555)*(e - 10.0);e = 6.11 * exp(5417.7530 * ((1/273.16) - (1/dewpoint)))

The range of humidex values and the associated degree of comfort is given below:

Less than 29	: No discomfort
30 to 39:	Some discomfort
40 to 45:	Great discomfort; avoid exertion
Above 45:	Dangerous
Above 54:	Heat stroke imminent

An extremely high humidex can be defined as one that is over 40. In such conditions, all unnecessary activity should be curtailed. If the reading is in the mid to high 30s, then certain types of outdoor exercise should be toned down or modified, depending on the age and health of the individual, physical shape, the type of clothes worn, and other weather conditions.

3.3.1.3 Net Effective Temperature (NET)

The net effective temperature (NET), is routinely monitored by the Hong Kong Observatory (Li and Chan, 2000) and takes into account the effect of air temperature, wind speed and relative humidity. NET is calculated as follows:

NET = 37 - (37-T)/(0.68 - 0.0014*RH + 1/(1.76+1.4*v**0.75)) - 0.29*T*(1-0.01*RH Eq. 3

with T= air temperature (°C), v = wind speed (m/s), and RH = relative humidity (%). NET has a higher value when the temperature is higher, but its value will be lower with higher wind speed and relative humidity. Taking acclimatization into account, it is believed that people of a particular place will feel cold or hot when the value of NET is equivalent to the lowest or highest of 2.5% of all values. In Hong Kong, a Cold (or Very Hot) Weather Warning is issued when the NET is forecast to be lower (or higher) than the 2.5th percentile (97.5th percentile). This procedure is also used for example in Portugal.

3.3.1.4 Wet-bulb-globe-temperature

The Wet Bulb Globe Temperature (WBGT) also combines temperature and humidity into a single number (Budd, 2009). In fact the real WBGT is also affected by wind and radiation. The WBGT is measured by a simple three-temperature element device. The first temperature, (Tg), is measured by the *black globe thermometer*, which usually consists of a 150 mm (6 inch) black globe with a thermometer located at the centre. The black globe temperature represents the integrated effects of radiation and wind. The second thermometer measures the *natural wet-bulb temperature* (Tnwb). It consists of a thermometer with its bulb covered with a wet cotton wick supplied with distilled water from a reservoir. Evaporation from the wet bulb cools the thermometer. The *natural wet-bulb* thermometer, like the *black globe* thermometer is not shielded from wind or radiation. This thermometer represents the integrated effects of humidity, wind and radiation. The final temperature element is the *(shaded) air temperature* (Ta). It is measured by a thermometer shielded from radiation - generally by being placed in a weather screen. It is the standard temperature normally quoted in weather observations and forecasts.

The three elements Tg, Tnwb, and Ta are combined into a weighted average to produce the WBGT.

$$WBGT = 0.7 \times Tnwb + 0.2 \times Tg + 0.1 \times Ta \qquad \text{Eq. 4}$$

The WBGT is widely used by researchers as an easily measured general heat-stress index in occupational medicine (see ISO 7242).

Instead of measuring the WBGT, the Australian Bureau of Meteorology uses an approximation based on standard measurements of temperature and humidity to calculate an estimate of the WBGT under moderately sunny and light wind conditions. Real variations of sunshine and wind are not taken into account. The formula is likely to overestimate the WBGT in cloudy or windy conditions, or when the sun is low or below the horizon. Under clear full sun and low humidity conditions the approximation underestimates the WBGT slightly. The simplified formula is:

$$WBGT = 0.567 \times Ta + 0.393 \times e + 3.94 \qquad \text{Eq. 5}$$

where: Ta = Air temperature (°C), e water vapour pressure (hPa).

3.3.1.5 Apparent Temperature

The Apparent Temperature (AT) is defined as the temperature, at the reference humidity level, producing the same amount of discomfort as that experienced under the current ambient temperature and humidity. Basically the AT is an adjustment to the *ambient temperature* (T) based on the level of humidity. An absolute humidity with a dew point of 14°C is chosen as a reference (this reference is adjusted a little with temperature). If the humidity is higher than the reference, then the AT will be higher than the T; and, if the humidity is lower than the reference, then AT will be lower than T. The amount of deviation is controlled by the assumptions of the Steadman (1984) model. AT is valid over a wide range of temperatures. It includes the chilling effect of the wind at lower temperatures.

A simple hot weather version of the AT, known as the Heat Index (see Eq.1), that focuses on T and RH, is used by the National Weather Service in the United States.

The formula for the AT used by the Australian Bureau of Meteorology is an approximation of the value provided by a mathematical model of the human heat balance. It can include the effects of temperature, humidity, wind-speed and radiation. Under Australian conditions the effect of full sun produces a maximum increase in the AT of about 8°C when the sun is at its highest elevation in the sky. Two forms are given, one including radiation (Eq 6a) and one without (Eq 6b). Here we present the non-radiation version that includes the effects of temperature, humidity, and wind:

AT = Ta + 0.348×e − 0.70×ws + 0.70×Q/(ws + 10) − 4.25 Eq. 6a
AT = Ta + 0.33×e − 0.70×ws − 4.00Eq. Eq. 6b

where: Ta = Dry bulb temperature (°C), E = Water vapour pressure (hPa),

ws = Wind speed (m/s) at an elevation of 10 meters, Q = Net radiation absorbed per unit area of body surface (W/m^2)

It should be noted that when using the term AT one must keep in mind that there are three different versions of AT (Eq. 1, Eq. 6a, Eq.6b).

3.3.2 Heat budget models

Heat exchange between the human body and the thermal environment (Fig. 3.2) can be described in the form of the energy balance or heat budget equation. The thermal comfort of an individual is the result of a response to the balance between heat gains and losses. This is often expressed in the form of the human energy balance as described by heat budget models. The human heat budget can be written as:

$$M - W - [Q_H(Ta, v) + Q^*(Tmrt, v)] - [Q_L(e, v) + Q_{SW}(e, v)] - Q_{Re}(Ta, e) \pm S = 0 \qquad \text{Eq. 1}$$

M Metabolic rate (activity)
W Mechanical power (kind of activity)
S Storage (change in heat content of the body)
Skin:
Q_H Turbulent flux of sensible heat
Q^* Radiation budget
Q_L Turbulent flux of latent heat (diffusion water vapour)
Q_{SW} Turbulent flux of latent heat (sweat evaporation)
Respiration:
Q_{Re} Respiratory heat flux (sensible and latent)

The meteorological input variables to the heat budget include air temperature (Ta), water vapour pressure (e), wind velocity (v), mean radiant temperature (Tmrt) including short- and long-wave radiation fluxes, in addition to metabolic rate and clothing insulation. In Eq.1 the appropriate meteorological variables are attached to the relevant fluxes. However, the internal (physiological) variables (Fig. 2.1), such as the temperature of the core and the skin, sweat rate, and skin wetness, which all interact in determining heat exchange conditions, are not explicitly modelled by the heat budget.

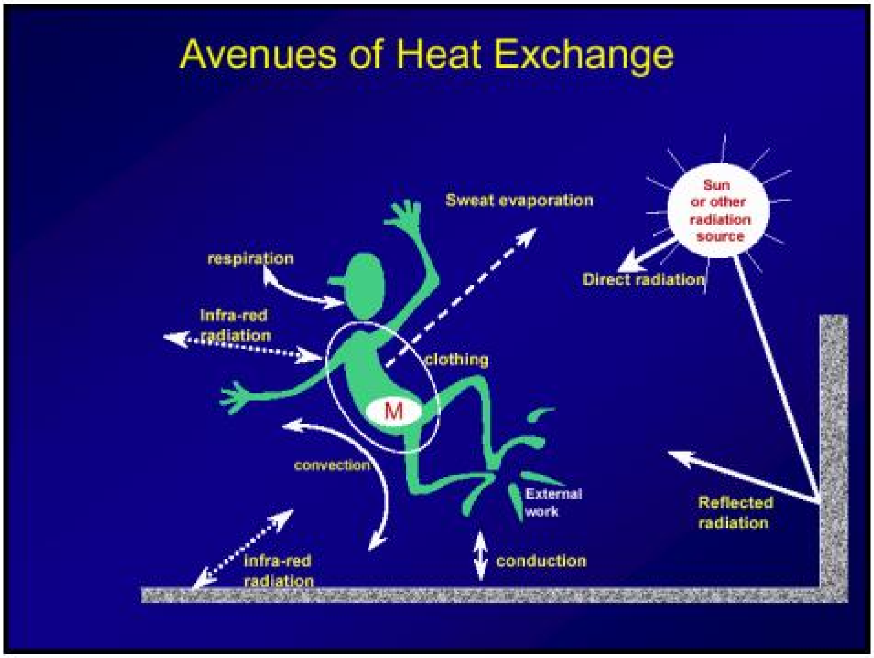

Figure 3.2 The human heat budget (Havenith, 2005)

A range of heat budget based indices exist which represent physiological response (strain) to heat. Three of the more widely used indices are presented below.

*3.3.2.1 Standard effective temperature SET**

The standard effective temperature SET* is defined as the equivalent air temperature of an isothermal environment at 50% RH in which a subject, while wearing clothing standardized for the activity concerned (this contrasts with the original ET* approach of Gagge et al. (1971) describing total heat loss from the skin), has the same heat stress (skin temperature T_{sk}) and thermoregulatory strain (skin wettedness w) as in the actual environment. SET* uses skin temperature T_{sk} and skin wettedness (w) for the limiting condition. The values for T_{sk} and w are derived from the Pierce `two-node' model of human physiology (Gagge et al. (1971, 1986)). For outdoor application SET* has been enhanced to OUT_SET* (Pickup and de Dear, 2000).

3.3.2.2 Predicted Mean Vote PMV

To predict actual thermal sensation, Fanger (1970) assumed that the sensation experienced by a person was a function of the physiological strain imposed on him by the environment. This he defined as "the difference between the internal heat production and the heat loss to the actual environment for a person kept at the comfort values for skin temperature and sweat production at the actual activity level". He calculated this extra load for people involved in climate chamber experiments and plotted their comfort vote against it. Thus he was able to predict the comfort vote that would arise from a given set of environmental conditions for a given clothing insulation and metabolic rate.

The final equation for optimal thermal comfort is fairly complex. However, ISO Standard 7730 includes a computer programme for calculating PMV (Predicted Mean Vote) on the ASHRAE 7-level thermal sensation scale.

3.3.2.3 Perceived Temperature PT

Fanger's (1970) PMV- (Predicted Mean Vote) equation, including Gagges et al's. (1986) improvement of the description of latent heat fluxes, with the introduction of PMV*, is generally the basis for the operational thermal assessment procedure entitled Klima-Michel-model (Jendritzky et al. 1979; Jendritzky et al. 1990) which is used by the German National Weather Service (Deutscher Wetterdienst; DWD). The output parameter is "Perceived Temperature, PT" (Staiger et al. 1997) which takes into account a certain degree of adaptation given various clothing ensembles. The Perceived Temperature PT is defined as the air temperature of a standard environment that would produce the same thermal stress as under the actual environment. At the DWD this procedure is run operationally taking quantitatively acclimatisation into account by using the HeRATE approach (see section 3.3.4.1 and section 4.3.2). To date the DWD is the only NMHS running a complete heat budget model (Klima-Michel-model) on a routine basis. The output is used for various applications in human biometeorology.

3.3.3 Holistic approaches

Another commonly used approach in evaluating heat response is the "synoptic" approach (see Chapter 4). This involves the classification of days into holistic "air masses" or "weather types", which encompass not only temperature but measures of humidity, cloud cover, pressure, and wind (Yarnal, 1993; Sheridan and Kalkstein, 2004). The underlying philosophy of this approach is that humans and animals react to the suite of atmospheric conditions surrounding them, as described by a range of weather variables. An air mass-based evaluation considers, *a priori*, that the umbrella of air encompassing us plays the major role in our weather-driven reactions. Application of this approach in a number of predominantly mid-latitude locations has demonstrated that anomalous mortality levels are predisposed to specific air mass or weather types. Thus, if on a short term basis such air mass types could be forecast, then estimates of how the population might react to a given air mass situation, in terms of health outcomes, could be made. Operational heat/health warning systems based on the synoptic approach are described in Chapter 4.

3.3.4 Adaptation considerations

All of the indices cited above are *absolute*; that is, a particular meteorological variable is considered to have the same impact on the human body no matter where or when it occurs. There is much value to absolute indices, as they provide a measure of intensity for any extreme weather event, i.e. the meteorological stress. However, humans and other organisms also respond to weather in *relative* way; that is, we respond differently to the weather dependent upon the frequency of the particular extreme episode. This is due to the ability to adapt, at least to a certain level. Thus, a temperature of 42°C, with a relative humidity of 10 percent will have a much different effect in Rome than it will have in Cairo. In addition, such conditions in Cairo during May would elicit a different response than the same conditions occurring in mid-July. Thus, there is growing interest in *relative* biometeorological indices that have the capability of taking human differential response into account. Two such indices are presented below.

3.3.4.1 HeRATE

HeRATE (**He**alth **R**elated **A**ssessment of the **T**hermal **E**nvironment) (Koppe and Jendritzky 2005) is a conceptual model of short-term acclimatisation based on findings in adaptation studies. The procedure modifies absolute thresholds of a selected thermal index by superimposition of the (relative) experience of the population, in terms of the index over the previous weeks. The time series of the daily weights of the past are derived from Gaussian filtering. The absolute part is weighted by 2/3 and the relative part by 1/3. This procedure has the advantage that the modified thermal index can be applied without further modification to different climate regions and during different times of the year without the need to artificially define seasons and to calibrate it to a particular locale.

HeRATE is used operationally by the DWD in all applications of the Perceived Temperature PT (see 3.3.2.2).

3.3.4.2 The Heat Stress Index

Another approach to account for the relative responses is the Heat Stress Index (HSI), of Watts and Kalkstein (2004). The heat stress index (HSI) is a comprehensive summer index that evaluates daily relative stress for locations based on deviations from the norm. The index is based on apparent temperature (Heat Index, section 3.3.1.1) and other derived meteorological variables, including cloud cover, cooling degree-hours, and consecutive days of extreme heat. Statistical distributions of meteorological variables are derived for 10-day periods of the annual cycle so that percentile values for each parameter can be determined. The daily percentile values for each variable are then summed, and a statistical distribution is fitted to the summed frequencies. The daily HSI value is the percentile associated with the location of the daily summed value under the summation curve. Each day's HSI value varies between 0 (coolest) and 10 (most stressfully hot); thus a stressful value of 9.8 yields different meteorological values for cities in different climates. The HSI is currently being used experimentally to determine whether it should replace, or complement the existing Heat Index.

3.4 Summary

Heat stress can be assessed using simplified biometeorogical indices, composed of one, two or multiple meteorological variables, or heat budget models which are numerical models that attempt to describe, in mathematic terms, the body's heat gains and losses. The choice of method for assessing heat stress will depend on the resources available to HHWS developers. Daily biometeorological index or heat budget model values, along with health data (e.g. daily mortality counts), are used to identify threshold values beyond which the health effects of heat increase rapidly. Observed and forecast threshold values are often used as a basis for action within a HHWS. HHWS based on the synoptic air mass approach use weather forecast data to assess whether an air mass, historically associated with high mortality, will occur within the next few days. The forecast occurrence of such an air mass sets the stage for action. In the absence of health data extreme heat stress index values, associated with the 95th to 99th percentile are used as action threshold values.

4. HEAT/HEALTH WARNING SYSTEMS: DEFINITION AND METHODOLOGY

Catalysed by a number of serious heat events (HHWS), the development of heat/health warning systems as part of a broader Heat Plan (Matthies et al., 2008) at a variety of levels has been rapid over the last decade. The purpose of this chapter is to review the nature of HHWS with emphasis placed on system structure and mechanics.

4.1 What is a Heat/Health Warning System?

Interest in the development of heat/health warning systems (HHWS) has been quite recent; before the intense event of 2003, for example, very few systems existed in Europe (EuroHEAT, 2007).

In the context of this set of guidance notes, a heat wave is defined as an unusually hot period (relative to the local climate) that can lead to a negative health outcome among humans. An HHWS is designed to alert decision-makers and the general public of impending dangerous hot weather, and to serve as a source of advice on how to avoid negative health outcomes associated with hot weather extremes (WHO/WMO/UNEP, 1996). The development of an HHWS includes a number of steps, including accurate weather forecasting, dissemination of the watch/warning, identification of vulnerable population groups, interaction with stakeholders, implementation of a mitigation procedure, and a check of effectiveness, among others.

Although an effective HHWS can employ one of a number of meteorological procedures, and its nature may vary based on local population, political systems, and available resources, there are several aspects that must be universal.

First, all systems should consider local meteorology, demographics, and urban structure (Sheridan and Kalkstein, 2004; Kalkstein et al, 2008). A one-size-fits-all set of systems may not properly accommodate all locations, especially if developed within countries that span different cultural and climate zones. For example, in the US, a system was designed in the 1990s to call an excessive heat warning whenever the apparent temperature was forecast to exceed 41°C for three consecutive hours on two consecutive days, no matter where it occurred (NOAA, 1995). Such a system does not take into account the relative, rather than absolute, nature of weather's impacts upon a particular area.

Second, all systems should be based upon thresholds that are related to actual heat/health outcomes. HHWS trigger mechanisms should be geared to the point when human health actually deteriorates. This threshold varies greatly from place to place and also depends upon the scope of the system. It can also vary within a place; for example, the heat-health relationship may be more acute earlier in the summer season than later within the season at the same place.

Third, the HHWS nomenclature should be clearly understood by the public, local stakeholders, and decision-makers. Thus, on a national level, a standardized terminology along with understandable criteria and messages would help significantly with communication.

Fourth, all systems should be paired with a quality notification and response programme. These 'mitigation plans' include interaction with the media, and messages to the public as to how they should react to extreme weather.

Finally, all systems should be evaluated to determine their effectiveness. The evaluations need to incorporate the effectiveness of mitigation activities, as well as the appropriateness of the warning determinant itself (see Chapter 7).

4.2 The Framework for Development

A typical flow diagram (Figure 4.1) displays the sequence of events within the development of HHWS. Most HHWS begin with the establishment of certain thresholds of human health tolerance to the extreme weather. If these thresholds are exceeded, this would trigger the issuance of a warning or alert. The benchmark for issuing a warning varies from place to place, based upon differential local responses to extreme weather. However, in some cases, prior to HHWS development, correlations between negative human health outcomes (morbidity, mortality, heat load on the body) and extreme weather are developed to permit an estimate of those health outcomes based on forecast data.

In some locales, it is the national weather service office (NWS) that is responsible for issuing advisories and warnings for heat. In others the local public health agency takes responsibility for warning issuance having taken advice from their NWS about forthcoming conditions.

Forecasts issued by NWS are therefore used as the primary input into the HHWS. In some cases forecasts are used as input into algorithms that attempt to estimate the degree of negative health impact of the weather. If the expected negative impact is above a predefined level or if a situation is identified that has been associated with negative health outcomes during the calibration period, the responsible agency (whether it is the NWS or a local health department) issues a warning or alert. Although the meteorological input varies among systems, in all cases thresholds are determined beyond which expected human health problems increase. Beyond that point, information is disseminated to various stakeholders so action can be taken.

Usually there are two or three separate warning categories, a low level announcement to warn the population of impending stressful weather, a higher level issuance that tells people that the weather might be dangerous to their health, and the highest level warning or alarm, at which time a variety of *intervention measures* are put into place by the community. In all cases, warnings must be disseminated rapidly to the public and responsible stakeholders, or the effectiveness of the HHWS is greatly diminished (WMO, 1999).

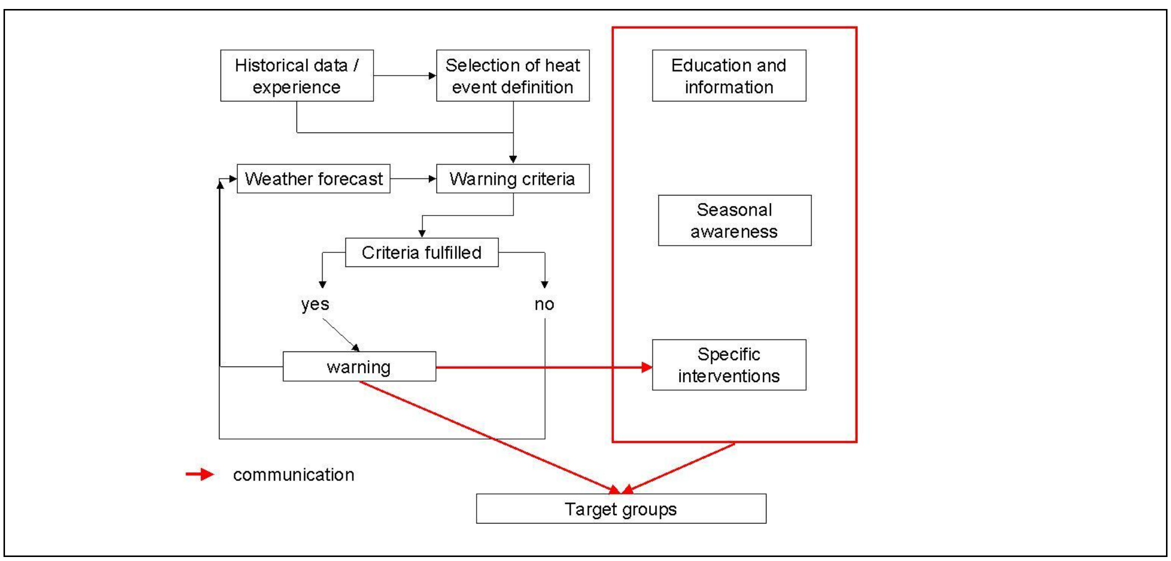

Figure 4.1 Flow diagram demonstrating the operation of a typical HHWS within a wider Heat Plan

4.3 Metrics of Heat-Event Determination in HHWSs

A number of methodological decisions must be made when an HHWS is developed. Because many of these systems have been initially employed at the individual city or country level, the range of methods presently utilized in HHWS is wide. Just as there is no universal quantitative definition of "heat event" or "heat wave," so too is there no single method by which heat situations, that may adversely affect human health, are identified and incorporated into a HHWS. Present systems generally incorporate one of several broad categories: single-metric, heat budget, synoptic, or other[1] (see section 3.3).

4.3.1 Single- or few-parameter methods

Of all the methodologies, utilization of the single metric of temperature, or a modified form of apparent temperature (see section 3.3.1) is perhaps the most common type of system. Temperature or apparent temperature methods are the sole approach in all systems in at least 13 countries, including Belarus, Belgium, France, Greece, Hungary, Latvia, the Netherlands, Poland, Portugal, Romania, Spain, Switzerland, and the UK (EuroHEAT, 2007). As all of these systems are initiated at the federal level, the entire country is under a similar system, although the thresholds vary within certain countries from location to location. The only exception to this is in Hungary, where only the city of Budapest is covered by a HHWS. Further, across the United States and Canada, a significant number of systems exist that are based on Heat Index or Humidex thresholds (Sheridan and Kalkstein 2004). These systems play various roles of importance, depending upon the local climate and susceptibility to heat events. In some cases, these systems have been replaced by synoptic-based systems; in other cases, the two run side-by-side. In Italy, apparent-temperature based thresholds are utilized in ten cities, four of which operate in conjunction with synoptic-based models (Accetta et al., 2005; Kirchmayer et al. 2004).

Despite its simplicity, there are a number of different ways in which temperature can be incorporated into a HHWS. The most straightforward is the exceedance of a maximum temperature threshold on a given day. The threshold may be based on a historical critical mark (an occasion arbitrarily obtained), or on comparison with negative health outcomes within the historical record. Single-day thresholds are climate-specific, ranging from 30°C in Belarus to 38°C in Greece (EuroHEAT, 2007). Though not the only part of the HHWS, in Phoenix, Arizona, USA, a warning threshold is reached when the forecast temperature exceeds a smoothed-curve of the season cycle of record daily maximum temperatures, with a threshold as high as 45°C in July.

Other permutations exist. In a number of HHWS, a threshold must be exceeded on a number of days before any warning is called. In Latvia, warnings are issued if the maximum temperature exceeds 27°C for 6 consecutive days *or* exceeds 33°C on 1 day (EuroHEAT, 2007). In the Netherlands, to meet warning criteria the temperature must exceed 25°C for 5 consecutive days *and* exceed 30°C on one day (Koppe et al., 2004). The ICARO index which signals the potential for warnings to be issued in Portugal is based on an exceedance of 32°C for 2 consecutive days (Paixao and Nogueira, 2002).

It should be noted that, in general, the European systems reviewed here are "top-down", in that the structure is most often set at the national level; in comparison, while national guidelines exist in North America and Australia, there is significant decentralization of the HHWS process, and thus a wider diversity of systems.

Recognizing the importance of overnight temperatures, a large number of systems (including Belgium, Montreal (Canada), England, France, Poland, and Spain) utilize thresholds for both maximum and minimum temperature in determining warnings (EuroHEAT, 2007; Kosatsky, pers. comm). Thresholds vary from 15°C in parts of England, to 25°C in parts of Spain for minimum temperatures, with maximums from 28°C in England to 41°C in Spain (EuroHEAT, 2007). In Budapest (Hungary), a daily mean temperature is used as a threshold (Paldy, pers. Comm.). Similar to the maximum temperature thresholds, there are also considerations of duration built into maximum and minimum thresholds; Belgium, France and England (2 days), as well as Montreal and Poland (3 days) all require thresholds to be exceeded on multiple consecutive days before a warning is considered (EuroHEAT, 2007; Kosatsky, pers. comm.).

In addition to these temperature thresholds, there are a number of HHWS that employ one of several apparent temperature metrics. Apparent temperature is a single variable that accounts for temperature as well as other meteorological factors, most typically humidity. These metrics could be beneficial in areas with very variable levels of atmospheric moisture, making the temperature alone perhaps less representative of the 'oppressiveness' of the weather than in locations where the humidity is relatively consistent from day to day. Thresholds of maximum apparent temperature are utilized throughout Italy, where the thresholds are adjusted by location, time of year, and duration of heat event (de'Donato et al. 2004, Kirchmayer et al. 2004). The apparent temperature is also used in Queensland, Australia, with regionally varying thresholds (e.g. 35°C in Brisbane, and 37°C in Amberly) that must occur on at least 2 consecutive days (Queensland Health 2004). The Heat Index, which incorporates temperature, humidity, and wind speed, is commonly utilized throughout all HHWS in the United States that are not based on the synoptic methodology, as well as in Switzerland. Official thresholds are set at a maximum heat index of 41°C, and a low of 27°C over two consecutive days for all regions within the United States, although each region is permitted to adjust these values to reflect local climatology (NWS, 1992). The Humidex is in use throughout all Canadian locations that do not incorporate the synoptic methodology (Marshall, pers. comm., 2006). Thresholds in Canada are set to the exceedance of maximum Humidex of 40 on two consecutive days. Thresholds of the Temperature-Humidity Index are utilized in Romania (EuroHEAT, 2007).

4.3.2 Heat budget

A more complex approach to the determination of HHWS thresholds is based on a heat budget model. This method, applied on a county level across Germany, is based on the Perceived Temperature (°C). The Perceived Temperature is evaluated within a broader framework known as the HeRATE (**He**alth **R**elated **A**ssessment of the **T**hermal **E**nvironment) approach (Koppe and Jendritzky, 2005; Koppe, 2005). It combines an approach that accounts for the short-term adaptation of human beings to the local meteorological conditions over the past four weeks with the "Perceived Temperature" in order to assess the thermal environment in a health-relevant way (see Section 3.4.4.1). This procedure aims at modifying a constant threshold above which negative impacts on human health would be expected by means of a variable part. By including short term adaptation, this system can be applied to data from different locations and at different times of the year without further modifications. Based on the constant part only, such thermal conditions are classified as heat load or cold stress if they fulfill some minimum requirements.

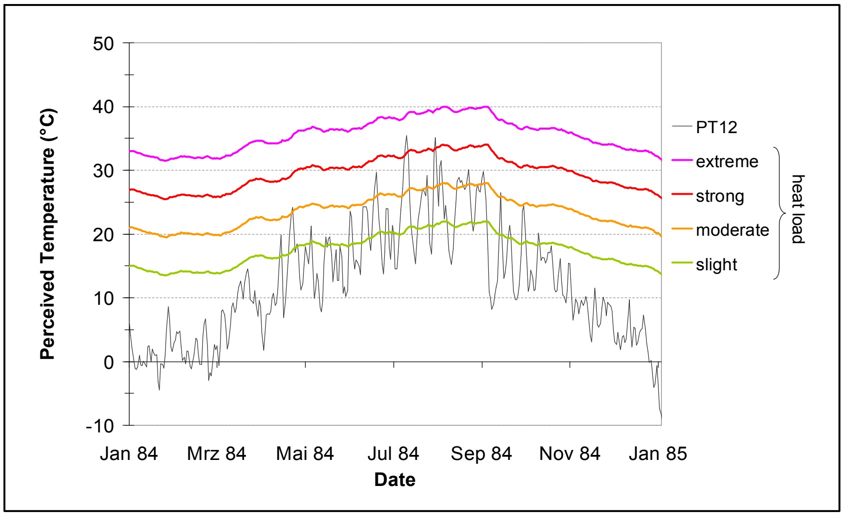

Figure 4.2 Example of the thresholds used in the German HHWS. A warning is issued in case the thresholds of a strong or extreme heat load are exceeded

Based on these adaptations, four different levels of heat stress have been determined: slight, moderate, strong, and extreme. These levels vary over time and place (Figure 4.2). Exceedance of a strong or extreme heat load is the warning threshold utilized, although a warning is also issued if the threshold for a strong heat load is not reached but Perceived Temperature is higher than 34°C.

4.3.3 Synoptic-based systems

Synoptic-based systems are presently implemented in four countries: the USA (28), Canada (3), the People's Republic of China (1), and Italy (4). In the USA, a number of systems are created as single or 'stand-alone' systems, with one centralized location serving as a reference for an entire forecast area affiliated with one National Weather Service office; in other cases, where two or more major cities are in close proximity, or there is significant meso-climate variability, multiple parallel systems are run. In Canada, the three systems in place are entirely within metropolitan Toronto, with different algorithms for each location. In Italy, all synoptic systems run alongside the apparent temperature systems discussed above.

Synoptic-based systems were first developed based on the Temporal Synoptic Index or TSI. This however has been succeeded by the Spatial Synoptic Classification (SSC; Sheridan 2002). The SSC incorporates temperature, dew point, wind direction, wind speed, cloud cover, and pressure, at four times per day. This information is used to determine which one of seven air masses (or a transitional type) is represented by the ambient atmospheric conditions at the values (?) from which the observations were drawn. The classification is based on a set of typical conditions for each air mass. These vary from location to location, and season to season, in a cohesive spatial and temporal manner (Bower et al., 2007).

The standardized mean summer mortality for each air mass is determined, and those air masses with statistically significant greater mortality than the normal are identified. Most often, two particular air masses are deemed "offensive", with respect to higher mortality values: dry tropical (DT) characterized by low atmospheric moisture contents and large insolation amounts and moist tropical plus (MT+) which is a hybrid type with high humidity and nocturnal temperatures often associated with extensive cloud cover (fig 4.3).

In many cases, air masses with mean overall increase in mortality are also associated with a higher standard deviation in mortality. To further refine mortality predictions, within-air mass algorithms have been developed to account for differences in air mass character from day to day, as well as time of season and persistence. It is these forecast algorithms that then predict mortality for input into the decision-making process on whether a heat warning should be called.

4.3.4 Other methodologies

While the above three methodologies comprise the bulk of all present-day HHWS, other methods are in operation. In Slovenia, there is no official methodology utilized; rather, the forecasters assess the situation based on experience (Cegnar, pers. comm., 2006). Similarly, in a number of the systems currently in use, including Germany, France, the United States, and Canada, the institution that is responsible for issuing the warning has some leeway in adjusting the thresholds discussed above upwards or downwards, to account for factors not included within the particular approach (EuroHEAT, 2007; NOAA, 1992).

4.4 How Warning thresholds are determined

As the above section shows, there are a number of different means utilized to define a 'heat event'. Similarly, there are a number of ways in which the precise threshold levels which instigate issuance of a warning are determined.

4.4.1 Determining thresholds

A number of HHWS thresholds are response-specific; that is, the threshold values are set at a level associated with a negative human response (WMO/WHO/UNEP, 1996). Though it is widely recognized that the health impacts of excessive heat are wide-ranging, including significant increases in morbidity as measured by hospital admissions (e.g., Semenza et al., 1999) or other metrics, it is mortality data that is most commonly used in HHWS threshold determination (Sheridan and Kalkstein, 2004). The reasons for this are straightforward: mortality data, unlike all other information on morbidity, is the most regularly collected and standardized; unlike hospital admissions (which can vary in reporting based on severity and may also depend on the health system), is binary in nature, and is available for the longest period of time. All synoptic-based systems in the United States are based on 24 years of mortality data (Sheridan and Kalkstein, 2004); the French systems are based on 33 years' worth (Pascal et al., 2005).

While raw-total mortality is what is initially obtained, a number of different ways of analysis have been undertaken. Given that heat exacerbates other ailments, and the official definition of a 'heat-related death' has long been known to underestimate heat's true impact (Gower, 1938), analyzing only official 'heat-related deaths' has not generally been a basis for a HHWS. As a number of studies have identified the elderly as the most vulnerable subset of the population, some HHWS are based solely on the mortality data of those 65 and older (e.g. Toronto; Kent et al., 2002). Others, such as the Italian systems (Michelozzi et al. 2005), are based on all non-accidental mortality. Most, however, are based on total, all-cause mortality, including all US synoptic-based systems and the French system (Sheridan and Kalkstein, 2004; Pascal et al., 2005).

Long-term mortality data are generally reduced to a 'baseline', or normal daily value, standardized to account for demographic changes over time (Sheridan and Kalkstein, 2004). Within-season adjustment is also necessary, especially in places that have a typical temporary out-migration during portions of the summer, such as Italy in August (Michelozzi et al., 2005). From this baseline, daily 'anomalous mortality' can be calculated and correlated with weather conditions.

There are a number of different means by which anomalous mortality data are evaluated. In all synoptic-based systems, the air masses that are associated with statistically significant anomalous mortality are identified; the algorithms defined above further refine this connection. In most cases, a predicted number of excess deaths is forecast, although in Toronto the historical data are utilized to predict the likelihood (in percent) of excess mortality occurring. The threshold is then exceeded in situations when at least one excess death is predicted; in Toronto, when an excess death is at least 65 percent likely (Sheridan and Kalkstein, 2004).

In other locations, different thresholds of the thermal metrics are set. In France, thresholds are set to correspond with temperature levels that have been associated with a mean 50-percent increase in mortality in urban areas, and a 100-percent increase in rural areas (Pascal et al., 2005). After some adjustments the French system uses thresholds that correspond to the 99th percentile of the regional distribution of minimum and maximum temperature. In Portugal's *Icaro* system, a threshold is set at the equivalent of a 31 percent rise in mortality for an announcement and at the equivalent of a 93 percent rise in mortality for an alert (Nogueira et al., 1999).

In some HHWS, no mortality component has been utilized in the determination of warning thresholds. One key example of this is in Germany, where the heat budget model evaluates the thermal stress on a typical human and bases thresholds on the different levels of stress, as noted. Though not explicitly based on a mortality response, a clear correlation with mortality has been established (Koppe, 2005).

In many other cases, however, the thresholds have been somewhat arbitrarily set. In a number of HHWS, the threshold is set by a percentile. For example in Belgium the 95th percentile of summer maximum temperature is the threshold (SPF, 2005). Other systems' thresholds are based on historical values, such as the US heat index threshold of 41°C, or the Canadian Humidex threshold of 40°C. While all of these thresholds are set to capture only the most extreme days, it should be noted that they have not been developed from or related to any specific health response.

One other important distinction among HHWS thresholds is their seasonality. As much research has shown that heat vulnerability varies through the season, with higher vulnerability earlier in the warm season (Smoyer, 1998; Kalkstein, 2002; Basu and Samet, 2002, Dessai, 2002; Kysely, 2004), some warning systems account for this differential variability. As mentioned above, the HeRATE system in Germany accounts for short-term acclimatization within its calculation of the threshold PT (Koppe, 2005). Similarly, air mass character within the synoptic-based systems varies seasonally. Because 'time of season' is typically utilized in predictive algorithms for these systems, synoptic-based systems account for intra-seasonal acclimatization (Sheridan and Kalkstein, 2004). While other thresholds can be made to be variable, most apparent-temperature or temperature based HHWS do not vary thresholds over the course of the year.

4.4.2 Defining and determining different levels of warnings

Most of the HHWS have more than one level of warning, and there is little consistency in the nomenclature for the different warning levels. The level called "Alert", for instance, means in England that a heat wave is expected within three days, but in Belgium signifies that the heat wave has already started. In some systems no name is given to the different levels of warnings at all and the warning levels are referred to as "level 1", "level 2", "level 3" etc. or as "green", "yellow", "orange" and "red" (EuroHEAT, 2007).

There are several ways to distinguish the levels of warnings. One way is to distinguish the warning levels based on the time until the event (Table 4.1). In some HHWS the lowest level of alert is active during the whole operating season of the HHWS. This level indicates that there is no risk for a heat wave and is often used to raise the general awareness of the potential danger of heat for human health and to provide the general public with information on how to behave in case of a heat wave as well as to educate health care professionals. Some of the HHWS have one or more pre-alert levels. This level is activated in case a heat wave is forecast to arrive during the next few days.

During a heat wave the severity can determine the level of alert. The heat wave levels are either graded depending on the intensity of the heat wave or on the duration, or in some cases a combination of both. In some HHWS, soft limits are used to increase the level of warning in case an "emergency" or very severe situation occurs, or the predicted level of mortality increase is used for increasing the warning level. In Belgium apart from the duration the ozone concentration also determines the level of alert (SPF, 2005).

Table 4.1 HHWS levels based on the time until the event or magnitude during event

	Examples of nomenclature	**Description**
Pre-alert levels (Temporal)	Seasonal vigilance	Activated during the whole summer season, though no heat event is forecast
	Outlook	A heat event is expected during the next 3-5 days
	Watch (warning)	A heat event is expected within the next 24-48 hours
Alert level (Severity)	Heat Alert Heat Advisory Warning Severe Weather Warning	Moderate heat event occurring or imminent
	Excessive Heat Warning Extreme Heat Alert Heat Emergency Maximum Mobilization Extreme Weather Warning	Significant heat event occurring or imminent

4.4.3 Other considerations with warnings

One significant concern in the development of HHWS thresholds is the frequency with which warnings are called; that is, to define at which point heat stress conditions become "sufficiently hazardous" to human health in a given population to warrant a warning (Kovats and Koppe, 2005). What "sufficiently hazardous" means depends on the scope of the HHWS. If the aim of a system is, for example, to prevent as much heat-related mortality as possible a low threshold has to be defined (e.g. T1 in Figure 4.3). In this case, a lower threshold may be chosen, and while the amount of lives that could be saved could be very large (amount a in Figure 4.3), the cost would be high and warning fatigue may set in. Another possibility would be to define only very severe situations as "sufficiently hazardous" (threshold T3 in the example). The aim of such a system is to prevent only the mortality peaks during very extreme conditions. As such conditions are very rare and might occur only once in several years, the total number of lives saved with such a system is smaller (amount c in Figure 4), although the costs to run any mitigation would be less.

Present systems vary significantly. Many of the synoptic-based systems, operating on the principle of statistically significant increases in mortality, identify increases in mortality of between 5 and 10 percent as targets for warning issuance. A long-term analysis of 50 years' worth of historical data suggest that, were warnings issued based solely on the system output, the synoptic-based Toronto system would have a mean of 4.5 warnings per year (1.4 higher-level extreme alerts, 3.1 lower-level alerts), with variability from 0 to 19 in any particular year (Kent et al. 2002). On the other hand, the higher-threshold French system, with a required 50- or 100-percent rise in mortality, results in less than one warning per year (Laaidi et al., 2004).

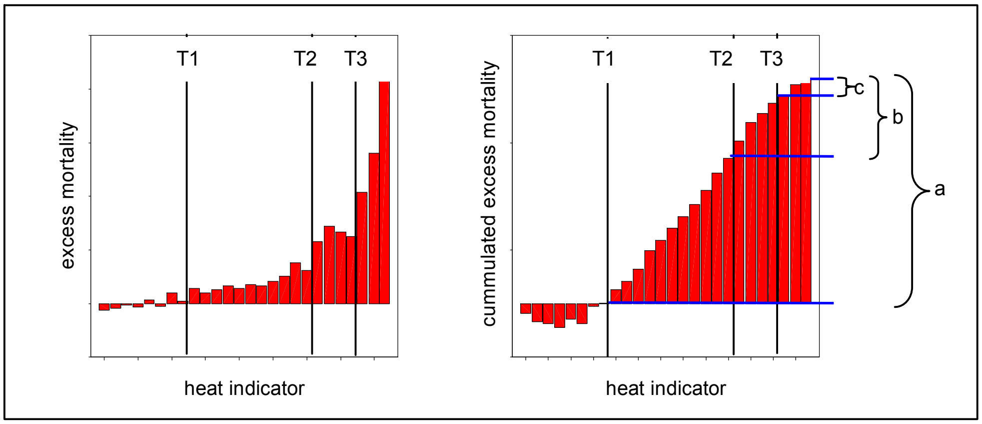

Figure 4.3 Example of the relationship between temperature and excess mortality during summer (left) and cumulative excess mortality (right). T1 – T3: thresholds; a,b,c: amount of mortality that can be prevented when applying the different thresholds in case of a 100% effective HHWS

Another cost-related concern involves the period of time during which the HHWS is active. Most systems operate only during the time of the year in which heat waves are most likely to occur, in order to reduce costs. This period certainly varies across the different climate zones. In the northern hemisphere middle-latitudes, systems generally run through the end of September (e.g., USA, Canada, Germany, Italy) or October (Spain). A more important concern due to the importance of early-season heat waves is the beginning of the heat season. The operating season starts in Germany in April, the US and Canadian synoptic systems begin in May, and most of other systems begin in June (EuroHEAT, 2007; Sheridan and Kalkstein, 2004).

4.5 Warning Issuance

HHWS differ in the way warnings are issued. Some systems only issue a statement in case the pre-alert or alert level is reached. Other systems issue statements daily, whether a pre-alert or alert level is reached or not.

Also the number of warnings issued per day varies within the systems between one time (generally in the morning) and three times (morning, noon, afternoon). In some HHWS the warnings are explicitly cancelled in case the weather forecast changes or when the heat event is over. Other systems simply “cancel” their warnings by not renewing them.

Several significant spatial issues arise in light of the warning systems presently utilized in HHWS. First and foremost is the spatial cohesiveness across different regions. In a number of systems, such as France (Figure 4.4), the threshold is defined to account for climatological differences (InVS, 2005), to define a more cohesive warning region when heat events arise, although on any given day the spatial variability in the meteorological forecast may not always coincide with these different thresholds. Another concern is in the areas where different jurisdictions cross. In Europe, though many countries have individual systems, there is no international cohesiveness at present, signifying that those living on either side of a border region may be subject to different levels of warning. In the US and Canada, it is where one forecast region ends and another begins (often not coinciding with significant political boundaries) that concern is raised. No published work has evaluated this concern.

Another concern involves the distinctions that are made within a given region, particularly between urban and rural areas. Some research has suggested that urban residents may not be more vulnerable than rural residents (Sheridan and Dolney, 2003), although this depends upon a number of other factors, including social status, building structure, and access to cooling systems. Especially since the sources of any HHWS message (media, health agency, etc.) tend to be located in larger urban areas, in addition to the fact the urban heat island results in urban areas being warmer (Oke, 1979), many of those that are not located in cities perceive that the message is not addressed to them. At present, a number of systems are aimed at broader areas, such as the county level in Germany or the department level in France (InVS, 2005); in other areas, such as China, a system is only in place for Shanghai and therefore does not cover adjacent rural areas (Tan et al., 2004), and in a number of US forecast offices, urban areas are placed under warnings more often than rural areas.
Finally, most of the HHWS do not explicitly account for indoor conditions, as warning criteria are based on outdoor meteorological observations and forecasts. Much of the susceptible population, however, spends most of their time indoors. The potential danger of indoor thermal stress can either be assessed by setting the thresholds for the heat warnings based on the relationship between health and outdoor temperature, or by including information about the relationship between outdoor and indoor thermal environment. In Germany, there is qualitative information about the thermal stress indoors for a realistic worst case residential building, based on the modelled relationship between outdoor meteorological conditions and indoor heat stress (Becker and Pfafferott, 2007).

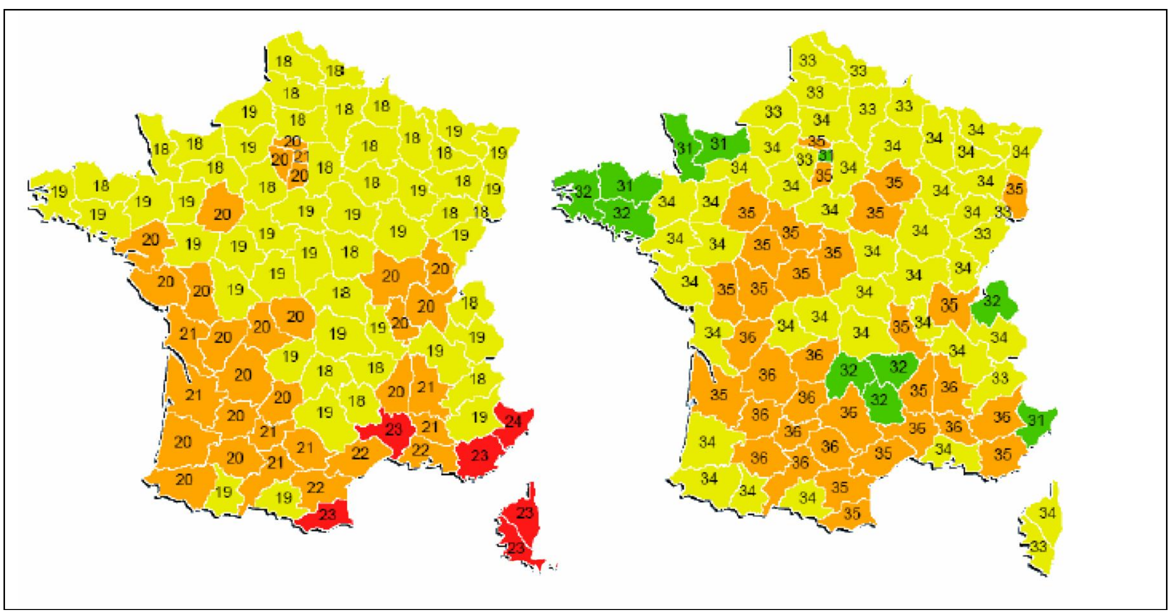

Figure 4.4 Thresholds of minimum (left) and maximum temperature (right) in France (InVS, 2005)

4.6 The Future of Present Day HHWS

HHWSs are an important adaptation strategy for adapting to a changing climate. Due to climate change, an increase in the number of heat events is very likely (IPCC, 2007). Thus HHWSs can help to mitigate the impacts of an increased number of heat events in the future.

A HHWS that is constructed based on a historical relationship between health impacts and thermal environment will also have to face these changes in climatic patterns. It can be assumed that populations adapt to climate change not only due to the implementation of HHWS but also through acclimatization (physiological adaptation). In addition to a changed exposure to heat, there are also several socio-economic and individual risk factors (see Chapter 2) that may change during the coming decades. Therefore, it is necessary to adapt the warning systems to actual climatic conditions and general adaptation status of the population, and to define the thresholds for issuing warnings in a way that accounts for changing vulnerability patterns. Indeed, research on trends in the heat/health relationship in the US (Davis et al., 2004) have shown a decreased vulnerability from the 1970s to 1990s, though future scenarios suggest an increase in heat vulnerability in the future with increasing elderly populations (e.g. Hayhoe et al., 2004).

A warning system that, for instance, is based on a “historical” percentile of minimum and/or maximum temperature will call more warnings in a warmer world than it was originally supposed to, leaving the population more inclined to ignore warnings. However, while revising a HHWS and changing the thresholds upon which warnings are issued, one should be aware of the aim of the system. Is the aim of the system to protect at-risk individuals or to avoid peaks in overall mortality? Further, has the vulnerability of at-risk individuals changed? Has the number of at-risk individuals changed, or both?

Another issue is that of air conditioning. With increasing temperatures, the use of air conditioning will increase in countries that can afford it to reduce individual exposure. Thus, on the population level a reduced exposure to heat will alter the relationship between outdoor thermal environment and health impacts. However, those with no access to air conditioning, or those that work outdoors, will not have any reduced vulnerability, and may indeed be more vulnerable if the heat generated by air conditioning warms the environment further. It is however questionable if it makes sense to include such considerations while evaluating and adapting existing HHWS, as changes in the thermal stress / mortality relationship at the population level may not be representative of the individual level.

In some HHWS big heat events are used to recalibrate the warning procedure. Adjustments may however be necessary only in some cases. It is important that warnings are issued in case of a heat event and that there is a set of effective intervention measures. But no adjustments may be necessary to forecast heat-related mortality more accurately, as it is unlikely to increase the effectiveness of the system. Moreover, due to the rareness of very extreme events, statistical relationships may be significantly altered by these “outliers”.This may result in making warning algorithms less useful for more “ordinary” heat events.

It should be also considered whether to combine heat warnings with air quality warnings or not. The probability of having high ozone levels in case of a heat event is relatively high as there is some evidence of the synergistic effect on mortality of high temperatures and ozone levels (Analitis et al., 2008). However, heat warnings and ozone warnings often address different target groups. While heat warnings often address the elderly and frail who spend most of their time indoors, where ozone levels are low even if they are high outdoors, ozone warnings are in general targeted to the population groups with outside activities. Furthermore, while heat warnings attempt to minimize risky behavior that may put the individual at risk, ozone warnings attempt to minimize behavior such as driving automobiles that will collectively increase ozone levels. Further, systems that advise the public on high ultraviolet radiation levels may also lead to confusion on how to respond on high-risk days.

In spite of the strides made in the development of sophisticated HHWS around the world, there are still inherent weaknesses with the systems, some of which can be addressed, and others that will always remain. For example, no system can highly accurately forecast the negative health outcome, such as mortality, because there are so many additional non-meteorological variables, or confounding factors, that impact death rates. Thus, the mortality/weather relationship does not correspond well to a dose/response relationship.

Little has been done to develop specific warnings for particularly vulnerable groups, such as the elderly, obese, or very young. Although messages often mention that these individuals are more susceptible to heat problems, systems are often designed for the population at large. For this reason, certain specific systems are being planned to target particular groups. For example, in the Desert Southwest of the U.S., many poor people only have "evaporative coolers" available to deal with excessive heat. These coolers, which work on the principle that evaporation will cool air coming into the house during very dry conditions, are ineffective when the weather becomes more humid. Thus, plans are being developed for a specialized "evaporative cooler warning system", to warn individuals that their coolers are ineffective because of more humid conditions (Kalkstein and Kalkstein, 2004). On the other hand, many systems have been based on heat/health responses that have focused on urban areas, and many mitigation plans focus predominately on urban residents. However, some research has indicated that rural population responses may be as extreme as urban ones (Sheridan and Dolney, 2003). Thus, while targeting of specific population sub-groups may be desirable, they should not lead to a confusion of the general population, or to making certain sub-groups feel as though they are not vulnerable to heat. Further, the implementation of different systems for different sub-groups may be feasible only in the more developed countries where more sophisticated communication systems exist.

4.7 Summary

The overall aim of an HHWS is to alert decision-makers and the general public of impending dangerous hot weather, and to serve as a source of advice on how to avoid negative health outcomes associated with hot weather extremes. Typically HHWS are composed of a number of elements which include weather forecasting, a method for assessing how future weather patterns may play out in terms of a range of health outcomes, determination of heat stress thresholds for action, a system of graded alerts/actions for communication to the general population or specific target groups about a pending period of heat and its intensity and to government agencies about the possible severity of health impacts.

HHWS are often part of a wider Heat Plan, which not only embraces the HHWS itself, but considers education and awareness-raising; heat event preparedness and guidance on heat avoidance actions; and heat risk governance; a communication plan; a programme of evaluation; a health surveillance system; and advice on longer term strategies for reducing heat risk. The structure of HHWS varies significantly between cities, regions and countries because human and technical resources and heat/health associations are usually geographically specific (Table 4.2).

Table 4.2 Currently operational HWWS

Country	*Threshold*	*Thresholds based on historical mortality*	*Excess mortality forecast*	*Duration of heat event included*	*Seasonality or adaptation included*	*Regionally variable thresholds*	*Human expertise*
Australia (Queensland)	Tapp			2 days		X	X
Belarus	T						
Belgium	Tmax/Tmin/ Ozone			3 days			
Canada							
Toronto region	Air Mass	X	X	X	X	X	X
Montreal	Tmax/Tmin			X			
All others	Humidex			X			
China							
Hong Kong	ET	?	?	?	?		?
Shanghai	Air Mass	X	X	X	X		X
France	Tmax/Tmin	X		3 days		X	X
Germany	PT			2 days	X	X	X
Greece	Tmax			X			
Hungary (Budapest only)	Tmean	X					
Italy	Air Mass/Tapp	X	X	X	X	X	
Latvia	Tmax			X			
Netherlands	Tmax			X			
Poland	Tmax/Tmin						
Portugal	Tmax	X	X	X		X	X
Romania	ITU						
Slovenia[7]	Forecaster						X
Spain	Tmax/Tmin	X				X	X
Switzerland	HI						
UK (England/Wales)	Tmax/Tmin	?		X		X	
USA							
Synoptic*	Air Mass	X	X	X	X	X	X
All other	HI			2 days		X	X

T=Temperature, Tapp=Apparent Temperature, Tmax=Maximum Temperature, Tmin=Minimum Temperature, Tmean=Mean Temperature, HI =Heat Index, PT=Perceived Temperature, ET=Equivalent Temperature, ITU=Temperature Humidity Index

**Seattle (Washington), Portland (Oregon), San Francisco and San Jose (California), Phoenix and Yuma (Arizona), Dallas and Houston (Texas), Minneapolis (Minnesota), Chicago (Illinois), St. Louis (Missouri), Dayton, Columbus and Cincinnati (Ohio), Philadelphia (Pennsylvania), Washington (DC), Baltimore (Maryland), New Orleans, Monroe, Shreveport, and Lake Charles (Louisiana), Little Rock and Fort Smith (Arkansas), Memphis (Tennessee), Jackson and Meridian (Mississippi).*

5. RISK COMMUNICATIONS: HEAT/HEALTH WARNINGS TO STAKEHOLDERS AND TO THE PUBLIC

5.1 Essential Elements of a Warning System

Meteorologists have a crucial role to play in dealing with the consequences of hazardous weather phenomena, which may end up as disasters. This applies equally to a situation of extreme heat as it does to any other threat. In all cases where a warning needs to be issued, scientific knowledge alone however will not solve the problem. Meteorological Services must work with other organizations and decision-makers at the local and national levels, including emergency management, the media, and voluntary organizations, to create effective preparedness and mitigation plans and strategies, warning systems, and public awareness and education programmes. The first step in setting up a warning system is to recognize when there is a need to warn the public of a particular meteorological hazard such as a heat wave.

5.1.2 The need to warn

The public expects to be warned of any natural phenomena that endanger life and property. In the case of excess heat, communicating the risks of hot weather and heat waves and what to do are recommended elements of a summer and heat wave prevention strategy. Warning in good time allows proper action to be taken, depending on the type and severity of the warning. Weather warnings concerning heat incorporate a high degree of urgency and severity of expected conditions. They are intended to alert the public in an attention-grabbing fashion. Heat warnings like all other meteorological warnings are usually issued when conditions are forecast to exceed predetermined criteria (see section 4.3), are amended or updated as required and are given priority in dissemination over other routinely produced weather products.

5.1.3 Decision to warn

Issuing timely warnings is a high priority challenge for the staff of an NMHS. Responding to the challenge requires a thorough understanding of the many factors influencing a successful decision to warn. Such factors include (but are not limited to) knowledge of conceptual models and atmospheric conditions favourable for hazardous weather to occur, as well as expertise in interpreting data sets from radar, satellites and NWP models. A methodology for effective decision-making is similar to that as in other occupations and businesses such as medicine, power plant management or aviation. Awareness of the situation, that is to say, the anticipation of how events are likely to develop plays an important role in decision-making. Furthermore, it implies sensitivity to respond to developments that may be possible if the conditions change. An essential element of a successful warning decision is a plan with which all staff must be familiar with and which will be the basis for training and drills. The plan should also be used for reference during a similar severe event regardless of personnel on duty. Other components of the plan, which should be understood by the operational personnel, include contact information for key officials and the media, content of the warning, frequency of issuance, and dissemination methods.

5.1.4 Definition of a warning system

The goal of any warning system is to maximize the number of people who take appropriate and timely actions for the safety of life and protection of property. Basically all warnings start with the detection of a hazard and end with getting the people out of harm's way. An integrated warning system for weather-related hazards, includes observing networks, prediction systems, and mechanisms for dissemination and communication with end-users. One may think of the warning process as a hierarchy of warning systems. The weather warning system provides weather-related hazard information, which may be used as input to trigger the mechanism for issuing, for example, health alerts.

Observation and detection includes the traditional scientific role of meteorologists. The forecaster analyzes data from remote sensing devices such as radar and satellite and on-site observing devices such as traditional instrument shelters, and any additional information to prepare the forecast. If hazardous weather, based on predetermined thresholds, is forecast, a warning is prepared for dissemination and communication with end-users. However, predictions are not in themselves useful unless they are translated into a warning and action plan, which the public can understand and unless the information reaches the public in a timely manner.

The public weather service function of NMHSs is the principal means of communicating hazardous weather information and understanding to the general public and to government decision-makers tasked with the safety of their citizens' lives and livelihoods. Communication is complete only after the information is fully received and understood and even then these products by themselves are not a stimulus to response action. Normally, people in a threatened area will first assess their personal risk and act depending on the content and clarity of the message; the credibility of issuing organization; and the state of preparedness of receiving authorities and agencies (WMO, 1999).

A very important element of a warning system is the education of the public about what warning systems can and cannot provide. One of the major problems with any warning system is the ability of the end-user to understand the uncertainty in the prediction of a hazard. Because NMHSs produce routine forecasts daily, the public are inclined to accept the forecast and criticize the forecaster when the forecast is "wrong". What is not well understood is that the atmosphere is, at times, quite unpredictable. However, forecasters do not on these occasions withhold their predictions; instead they are communicated with a high level of uncertainty. It is this latter information that is not conveyed very clearly to, or understood by, the end-user.

5.1.5 Content of a warning

The actual content of a warning message that is delivered to members of the public is of critical importance in guiding what people think and in leading them to take appropriate action to protect themselves from the hazard. This makes the wording of warnings crucial to the effectiveness of the service. Important points to be kept in mind when composing a warning are:

- Clear definition of the components of the message,
- Simplicity of the message,
- Personalization of the message and description of the actions required,
- Prioritization of the order of importance of the information,
- Use of plain language,
- Inclusion of a statement of recommended action,
- Ensuring that shortening of the message by broadcasters does not distort the meaning of the warning.

The point about recommended action is especially important. An effective warning message should recommend ways that the public can achieve protection, including safety rules or guidelines for appropriate action. These recommended actions should be worked out in agreement with disaster managers, following established regulations. A message that effectively describes a danger but offers no suggestions for protection simply tends to be denied or reinterpreted by recipients. The public could generate protective actions for themselves based on misinterpreted folk wisdom or an incorrect understanding of the threat that would increase their level of likely injury.

5.1.6 Language

To influence the recipients of the warning, care should be taken to ensure that the language and vocabulary used is appropriate to the region or country, the culture and the user needs. Warnings should be issued not only in the official language of a country but also in other commonly used languages where necessary. The use of technical terminology and jargon depends on the recipients. Whereas the use of highly technical terms and abbreviations is to be avoided for the general public, it can be used in communicating with the other decision-makers and governmental agencies, if this has been agreed upon in advance. In all cases, however, the use of clear, concise, simple words are the most effective for conveying meaning and avoiding potential confusion. The fact that the public can often see or hear a warning only once, adds to the need for clarity and simplicity of the message.

5.1.7 Criteria for issuing warnings

Criteria and thresholds need to be defined as part of the warning system. These thresholds when exceeded, will automatically lead to the issuance of a warning. Very often criteria and thresholds may differ from region to region and even in different regions within the same country. The frequency of exceeding thresholds is a factor for consideration when selecting them. For example, while summer temperatures of 40ºC may be considered normal in some countries, the same temperatures in a mid-latitude country with a temperate climate may present serious challenges to the authorities and risks to the public if they are unprepared for it (see section 4.4.1).

5.2 Dissemination of Warnings to the Public

5.2.1 Effective dissemination and communication

Forecasts and warnings are highly perishable products and should be disseminated rapidly to the public in order to be of value. Resources available to a particular NMHS dictate, to a large degree, the level of sophistication of technological application for disseminating the information. However, in both developed and developing countries, technology is advancing and becoming more affordable and accessible. The question thus becomes how to disseminate the information in the most effective way to the intended audience. In order to carry out this function effectively, the staff responsible need to be well trained in aspects of preparing the information for presentation via various types of mass media such as radio, television and print as well as other media such as the internet and in the actual message dissemination itself. Warnings and forecasts not only need to be understandable, but also attractive so as to elicit sufficient interest and motivation for the user to read, listen to or look at and take action on. This requires NMHS staff to have effective communication skills, which can be gained through specialized training. In addition, skills relating to interacting with and rendering service to the media are very important, such as writing effective press releases, holding interviews, press conferences and press briefings. Needless to say, communication with the press is enhanced if journalists have a background in the general subject area.

5.2.2 Media for dissemination

Each different§ means of communication has its advantages and disadvantages. Television and radio reach the population at large and are ideal for the distribution of time-critical information such as warnings. Radio can reach a wide audience very rapidly in an emergency situation, whereas television has the advantage of presenting the information in graphical format. Newspapers, while useful for providing detailed and graphic information, and are a powerful medium for public education purposes, are not suitable for dissemination of warnings. Whatever medium of dissemination is used, it should be remembered that more and more information is becoming available to the public and it is essential that information, such as warnings, stands out clearly and is understood by the intended users.

In addition to the mass media, NMHSs use the Internet to disseminate weather forecasts and warnings. This is a versatile tool because a NMHS can display large amounts of information which can be easily updated. This may include raw data, forecasts and warnings and educational information. The Internet allows an NMHS to display its information in an attractive format including highly visual graphics and animations, which may attract and motivate users to consult it. Where required, information is targeted to specific or specialized users who are provided with specific forecasts via a password.

In some NMHSs, the public can call and speak directly to the staff but this may result in overloading of service lines at critical times. Restricted-use, unlisted, hotline numbers are normally available which permit urgent communication between the NMHS and government authorities or emergency managers to take place. Additionally, weather messages recorded on automatic telephone answering devices are effective in reducing the number of telephone calls to the forecast office.

The telephone paging system is another method that allows quick, simple messages or alarms about time-critical weather information to be sent to a list of individuals including emergency managers. Weather information is also made available through arrangements between NMHSs and mobile telephone providers who disseminate it to individuals who subscribe to the service. This may take the form of Wireless Application Protocol (WAP), a standard for transmitting interactive content over mobile phone networks. The prescriber receives WebPages on the display of a mobile phone. The Short Messaging System (SMS) is also a popular modern way of receiving weather information.

Press conferences or briefings are a useful method of effectively getting wide coverage of important events such as high-impact weather ranging from expected hot or cold spells. Whatever method is used, an effective dissemination system must provide appropriate information to emergency management officials and the general public in a reliable and timely manner. As communication facilities are liable to break down from time to time, back up methods have to be available so that the most urgent messages such as warnings can be distributed without interruption.

Very often the challenge facing an NMHS within a severe funding constraint is to provide the most cost-effective dissemination system. Often, the use of “off-the-shelf” technologies is the most cost-effective and efficient approach for preparation and dissemination of forecasts and warnings. In ensuring backup capability when the primary dissemination system fails, particularly during high impact or hazardous events, partnership arrangements to pool resources with the media and emergency services can be an effective approach.

5.2.3 Evolving and emerging communication technologies

The rapid development of Information Technology (IT) has placed considerable demands on NMHS in terms of providing improved weather products and enhanced information.

Advances in information and communication technologies have raised expectations in the broad area of health. This has resulted in the development of eHealth as a tool that enables cost-effective and secure use of information and communications technologies in support of health and health-related fields, including health-care services, health surveillance, health literature, education, knowledge and research. The Fifty-eighth World Health Assembly, urged WHO Members to consider establishing and implementing national electronic public-health information systems and to improve, by means of information, the capacity for surveillance of, and rapid response to, disease and public-health emergencies. WHO (2005 b).

5.2.3.1 *Implications for the design, packaging and delivery of weather information*

Text messages such as SMS are a very efficient means of transmitting short and timely messages to users with mobile phones, either on demand or as an emergency alert. Mobile communication systems already have the capability to transmit and receive graphics, voice and text in a similar way to television. The trend towards the mass use of different kinds of mobile devices to receive weather products and information will increase the need for:

- More compressed, compact weather warnings, including heat warnings;
- More time-specific and location-specific information.

To facilitate the delivery of weather information to next generation mobile devices, new standards for data and protocols will be required, as well as more efficient means of data packaging. One example of a possible solution is the use of XML, an open standard for data exchange between different computer systems over the Internet.

A web service is a distributed computing technology over the Internet, similar to XML in many respects and used for the exchange of data between computer systems. It is based on the client-server application model.

Meteorological content remains essential in exploring such new opportunities. The new communication systems support the vision of giving target groups the information they need in the easiest and most informative way. The system is a tool to deliver the message in ways that are easily understood and used, but the limitations on information interpretation, such as probabilistic statements should also be made known.

5.3 Coordination with users

In the broadest sense, coordination should be pursued with all sectors who are users of the meteorological information and whose mandate makes coordination with them essential to the effectiveness of their work. To ensure effective warning, coordination is required within the hazards community and with the media. For maximum effectiveness, warning systems need to be linked to organizations responsible for response actions. This holds true at local and national levels. A key to success is involvement of the local population and strong support for the coordination by the local political leadership.

Where meteorological hazards are concerned, the regular flow of reliable and authoritative warning information to the public, political leaders, responsible officials and affected institutions is vital.

5.3.1 Coordination with the hazards community

An NMHS's emergency plan for dealing with hazardous weather should be carefully coordinated with corresponding plans of agencies with emergency response responsibilities. The plan should be practiced regularly to ensure that all staff are familiar with their responsibilities under the plan, that the technological components are fully operational and that it fits in smoothly with the overall emergency response effort. Experience in many countries shows that time and effort invested in the development, maintenance and exercise of a good emergency plan will invariably yield substantial dividends when a real emergency occurs.

The maintenance of a regular flow of authoritative and factual information can pose a particular challenge during catastrophic events even when a functioning communications system exists. This is generally due to difficulties in obtaining and confirming information or in coordinating the many players involved in emergency response. These constraints can delay the release of official statements and may sometimes create an information vacuum. This vacuum may be filled by media personalities or outside experts who are less constrained in their comments and who may, inadvertently, contribute to public confusion.

5.3.2 Coordination with the media

Coordination with the media is essential in order to ensure timely and accurate dissemination of warnings. The various media are often in competition with one another to get the earliest story, or a new angle on the story. In order to ease this competition and to promote a consistent message, conference calls or hotlines involving the major media outlets are of prime importance. It is important to arrive at agreements with the media that during severe weather such as heat waves:

- Warnings should not be modified except in format;
- Warnings should be issued directly to the public as soon as possible and as close to verbatim as possible;
- Warnings should not be disseminated after expiration time;
- Viewers and listeners should be urged to monitor the development of the weather conditions.

5.3.2.1 Media accounts, everyday life and risk signature

The extent to which media accounts or stories shape people's behaviour is clearly a key question for risk communication practice. Research on risk suggests that different risks have the capacity to engender specific patterns of understanding and response. This is often referred to as 'risk signature'. This 'signature' of risk may be understood in terms of people's practical reasoning, in specific circumstances, about the material nature and potential social impact of a given risk. In this sense, the signature is neither a wholly objective nor wholly subjective attribute of the risk. Rather, it is about how the material characteristics are articulated in social terms. The differences in the structure of media accounts reflect the degree to which understandings can be grounded in terms of everyday experience. Media accounts will play an important role in shaping understandings according to the extent to which everyday experience can be called upon to provide a compelling account (WHO, 2006). The media should be considered as both mirrors of public perceptions and at the same time contributing to public perception. Systematically analysing those two functions should help us to take stock of public perception of risks for policy-making.

In particular the tendency toward panic reactions in response to catastrophic risks is something that should concern those involved in both industry and public health. The economic losses caused by over-reaction, or misplaced reaction, can be huge, as can the loss of human life. Often the risk management response is in proportion to the media coverage of the issue rather than the actual risk to human health. Policy-makers and regulators are not consistent in how they address risk, and society does not treat equivalent risks with the same degree of intervention. For example, deaths from road traffic accidents are not regarded in the same way as deaths from food poisoning and do not precipitate the same degree of media coverage and reactionary risk management.

5.3.2.2 Media monitoring

In modern society the mass media represents one of the most important means of communication between governments and citizens, and between information producers and consumers. The mass media is an important medium for profiling the issues and problems with which public opinion is interested and concerned. Therefore the potential for the media to play a critical role in communicating information about extreme weather-related health issues is immense. However, communication via the media, particularly related to environment and health, remains a weak area and continues to frustrate public health advocates. A lack of communication skills, resources and poor channels of communication between information sources and media and the private and public sectors can often make a bad situation worse (WHO ,2006). Accordingly it is critical that the media is monitored in terms of the role it plays in conveying general and specific information relating to the association between extreme weather events and health-related outcomes.

5.3.3 Aspects peculiar to heat/health risk communication

Early involvement of the media is recommended in order to initiate rapid communication when a heat hazard is forecast or detected. Experience shows that this is not always done. For example, the WHO Fifth Futures Forum, while dealing with case studies requiring rapid response, such as the heat-wave epidemic in France and Portugal in summer 2003, concluded that failures in communication were found to be the key features of the crisis (WHO, 2004). Experience has brought forth elements that contribute to success in risk communication. Some key considerations, based on best practice examples are provided in the following subsections below.

5.3.3.1 Trust

The overriding goal is to communicate with the public in ways that build, maintain or restore trust. The media plays a role in determining the level of trust the public displays. There is hence, an increasing need to gain a better understanding of the interplay between public perceptions and the media, communication strategies and policy initiatives and to investigate how public authorities can both earn trust and legitimacy when communicating about uncertainty and health risks (WHO, 2006).

5.3.3.2 Timely warning

The parameters of trust are established in the first official announcement. The message timing, candour and comprehensiveness may make it the most important of all communications.

5.3.3.3 Transparency

Transparency needs to be the first order of the day. Maintaining public trust throughout an event requires transparency (communication that is candid, easily understood, complete and factually accurate). Transparency characterizes the relationship between the event managers and the public. It allows the public to view the information-gathering, risk-assessment and decision-making processes associated with extreme events response. Governments should release information to their own populations, and to other governments and international agencies. Commitment to transparency on its own is insufficient. Equally important is, for example the need to ensure that those in the front-line of public communication — namely science and health journalists — have adequate tools and skills to perform their task and to detect when a commitment to transparency is not being observed (WHO, 2005).

5.3.3.4 The public

Understanding the public is critical to effective communication. It is usually difficult to change pre-existing beliefs unless those beliefs are explicitly addressed. And it is nearly impossible to design successful messages that bridge the gap between the expert and the public without knowing what people think. Early risk communication is directed at informing the public about technical decisions (known as the "decide and tell" strategy). Today, risk communicators teach that crisis communication is a dialogue. It is the job of the communicator to understand the public's beliefs, opinions and knowledge about specific risks. This task is sometimes called "communications surveillance". The public's concerns must be appreciated even if they seem unfounded.

5.3.3.5 What the individual can do

Risk communication messages should include information about what the public can do to ensure their own safety. It is important to agree with the media at the beginning of the heat season the key messages to announce and what key health professionals should do in order to avoid health impacts during heat-waves. The content of specific behavioural and medical advice varies across public health response plans and cultures. Passive dissemination of advice may not be sufficient to reach those people most at risk, therefore active identification and care of people at risk should be an integral part of any public health response plan.

5.4 Community of Practice

In order to establish an effective policy for dealing with warnings, especially for mitigation of the effects of extreme weather events such as heat waves, NMHSs should work closely with governmental authorities at policy and decision-making levels. This is important as it affects the allocation of resources by any government responding to the possible effects of expected high-impact weather. Despite efforts in this direction, work still needs to be done before this is achieved on a wide scale. Developing Communities of Practice is a way forward to integrate the meteorological community and user communities at national, regional and local levels to work together to remove gaps between provision and understanding and use of information. For example, an 'Air Quality and Health Community of Practice' in a particular country could comprise the Weather Forecasting Community, the Atmospheric Observation Community, the Hazard Alerting Community, the Public Health Officials and Local and Regional Air Quality Managers (Figure 5.1).

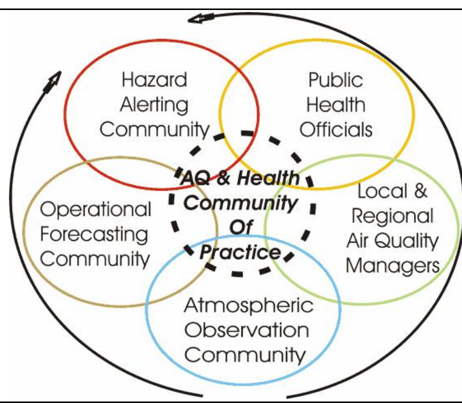

Figure 5.1 Example of an 'Air Quality and Health Community of Practice' structure
Source: *Gary Foley, US EPA*

5.5 Public Education and Outreach

Public education and outreach programmes aim to strengthen the links between the providers and users of the services provided by an NMHS so that individuals, communities and organizations can make effective use of the available products and services. This applies equally to warnings and services associated with heat/health. While the initiative to develop such public education and outreach programmes should normally come from the NMHS, it is preferable that these activities be undertaken together with partners such as educational authorities, emergency management agencies and the media. It is worth drawing a distinction between public education and outreach programmes and campaigns as follows:

- *Public education:* refers to products and services associated with learning about weather, climate and water, primarily within the formal education system;
- *Outreach:* refers to products or services about weather, climate and water that involve short-term contact with members of the public and other users of the services of the NMHS with the intention of providing information, raising awareness and interest.

5.5.1 Critical factors

The following are critical success factors in establishing a public education and outreach programme:

- *Understanding the needs of the target audience:* through having a clear understanding of their behaviours and attitudes;
- *Establishing an implementation plan:* based on clearly defined needs, goals, objectives and target audience;
- *Involving the target audience:* in the planning, implementation and governance of the programme;
- *Using the right people:* fully committed and with the appropriate range of knowledge and skills;
- *Making material widely available:* using hardcopy but also distribution based on modern technology;
- *Ensuring high-level support:* from key decision-makers and management;
- *Ensuring adequate funding:* and realistic consideration for sustainability and continuity of activities;
- *Coordinating initiatives:* to build upon or create synergies with existing initiatives;
- *Learning from successful initiatives:* and examples of public education and outreach programmes;
- *Ensuring evaluation and feedback:* to help improve the public education and outreach programme.

5.5.2 Target audience

The target audience is the group of people whose behaviours or attitudes the public education and outreach programme is attempting to change. In this case, the target audience needs to be segmented in such a way that the people in each segment have essentially the same characteristics. When considering the target audience, four common groupings are often used: geographical location; demographic characteristics; occupation;

behaviour pattern. The following are the various audiences that might be targeted by a public education and outreach programme addressing heat/health services:

- School and academic institutions;
- General public;
- People involved in recreational or economic activities;
- Media;
- Hazards community; and
- Governmental authorities.

Having identified the target audience, it is worth obtaining basic information as shown below that will help to provide a picture of the target audience and the community in which they reside.

- Why people in target audience behave as they do and what might make them change?
- What are the cultural and ethnic characteristics of the audience?
- What is important to the target audience?
- Does the audience believe there is a problem that needs addressing?
- What is the knowledge base of the audience?
- How does the audience receive and share information?
- Who are the opinion leaders and information disseminators in the audience?

A key component for success of any public education and outreach programme is to work in partnership with others. Agencies such as education ministries, universities, training institutions, professional bodies and trade associations can make a valuable contribution to ensuring that a programme is relevant and has the desired impact on the target audience. Educating the media is one way to educate the public. However, they will tend to focus on the impacts of a hazard and on the warning and will pay less attention to the need to understand what a warning can and cannot do for society. Cooperative programmes between the media and the NMHSs can help to improve public education.

On the social side of the question, it should be remembered that several generations that coexist within society will have different histories of exposure to heat hazards. It is important to remind the public constantly about hazards and their potential impacts.

5.6 Summary

Communication links the biometeorological and weather forecasting science components with the societal risk reduction components of a HHWS. A well honed communication plan is therefore crucial for the success of a HHWS especially in terms of how warnings get translated into actions. It is imperative that the risk associated with an impending period of anomalous heat is communicated precisely and adjusted according to the target group. Consequently bespoke messages, which may be action-threshold specific (e.g. health authority, emergency service, media, community action group) composed of clear unambiguous language, are an essential element of any HHWS. The same principles extend to the communication and outreach elements associated with wider Heat Plans.

6. INTERVENTION STRATEGIES

6.1 Heat Intervention

The intervention measures instituted by the community and the actions taken by individuals when heat warnings are issued determine the extent of impact of a heat wave. Like other aspects of HHWS, these measures are highly variable from one locale to the next and depend on available resources, the political structure, and the awareness that heat is a major health problem. The basic goals of intervention strategies during a heat wave are to help individuals:

- Maintain their core body temperature within a healthy range through appropriate changes in behaviors and activities;
- Recognize, within themselves and others, the signs and symptoms of heat stress; and
- Know what actions to take to reduce heat stress.

Interventions may be passively communicated through mass media (see Chapter 5) or may have active elements, such as warning providers of health or welfare services, or transporting at-risk individuals to cooling centres (Kovats and Ebi 2006). The interventions implemented depend on the local context, including cultural practices, human and financial resources, and other factors. As discussed in Chapter 5, stakeholders need to be involved in the design of intervention strategies to incorporate local knowledge of effective measures to reduce heat stress.

Most publications on preventing heat-related illness are from temperate, high-income countries. People in tropical countries have acclimatized to their warmer temperatures through clothing, housing design, and cultural habits (i.e. siestas during the heat of the day). However, population growth, development, and globalization have changed clothing, behaviors, and housing construction, and created large urban slums, thus increasing vulnerability to heat waves in regions that typically have been considered relatively heat tolerant. Further, increases in global mean surface temperature are resulting in regions and communities reporting temperatures that are close to the temperatures to which humans can physiologically adapt. Therefore, even tropical countries may experience heat waves.

Interventions can be categorized by individual and community-level responses (including responses by employers). The timing of which interventions to implement should be tied to the levels of warning used in the HHWS, with educational messages provided early.

6.2 Individual Level Responses

One goal of a HHWS is to build the capacity of individuals and communities to self-manage their responses through effective and timely strategies. Examples of comprehensive advice for individual actions during a heat wave are provided in Boxes 6.1 and 6.2 from the UK Department of Health (UK DoH 2005) and from the US Centers for Disease Control and Prevention on preventing heat-related illnesses, respectively (CDC, 2003).

Box 6.1

Advice on preventing heat-related illnesses from the Department of Health, UK

Listen to bulletins on radio and television and follow health advice.

Keep out of the heat

- If a heat wave is forecast, try and plan your day in a way that allows you to stay out of the heat.
- If you can, avoid going out in the hottest part of the day (11 AM – 3 PM).
- If you can't avoid strenuous outdoor activity, like sport, DIY (do-it-yourself home improvement), or gardening, keep it for cooler parts of the day, like early morning.
- If you must go out, stay in the shade. Wear a hat and light, loose-fitting clothes, preferably cotton.
- If you will be outside for some time, take plenty of water with you.

Stay cool

- Stay inside, in the coolest rooms in your home, as much as possible.
- Close the curtains in rooms that get a lot of sun.
- Keep windows closed while the room is cooler than it is outside. Open them when temperature inside rises, and at night for ventilation. If you are worried about security, at least open winders on the first floor and above.
- Take cool showers or baths, and splash yourself several times a day with cold water, particularly your face and the back of your neck.

Drink regularly

- Drink regularly even if you do not feel thirsty – water or fruit juice are best.
- Try to avoid alcohol, tea, and coffee. They make dehydration worse.
- Eat as you normally would. Try to eat more cold food, particularly salads and fruit, which contain water.

See advice if you have any concerns

- Contact your doctor, a pharmacist, or NHS (National Health Service) Direct if you are worried about your health during a heat wave, especially if you are taking medication, or have any unusual symptoms.
- Watch for cramp in your arms, legs, or stomach, feelings of mild confusion, weakness, or problems sleeping.
- If you have these symptoms, rest for several hours, keep cool, and drink water or fruit juice. Seek medical advice if they get worse or don't go away.

Helping others

- If anyone you know is likely to be at risk during a heat wave, help them get the advice and support they need.
- Older people living on their own should be visited daily to check if they are OK.

Source: UK Dott 2005

Box 6.2

Guidelines on managing heat from the US Centers for Disease Control and Prevention

- Drink more fluids (non-alcoholic), regardless of your activity level. Don't wait until you are thirsty to drink.

- Don't drink liquids that contain caffeine, alcohol, or large amounts of sugar – these actually cause you to lose more body fluid.

- Stay indoors and, if at all possible, stay in an air-conditioned place. If your home does not have air conditioning, go to the shopping mall or public library – even a few hours spent in air conditioning can help your body stay cooler when you go back into the heat. Call you local health department to see if there are any heat-relief shelters in your area.

- Electric fans may provide comfort, but when the temperature is higher than 35°C, fan will not prevent heat-related illness. Taking a cool shower or bath, or moving to an air-conditioned place is a much better way to cool off.

- Wear lightweight, light-coloured, loose-fitting clothing.

- Never leave anyone alone in a closed, parked vehicle.

- Although anyone at any time can suffer from heat-related illness, some people are at greater risk than others. Check regularly on infants and young children, people aged 65 or older, people who have a mental illness, those who are physically ill, especially with heart disease or high blood pressure.

- Visit adults at risk at least twice a day and closely watch them for signs of heat exhaustion or heatstroke. Infants and young children need more frequent watching.

- If you must be out in the heat:
  - Limit your outdoor activity to morning and evening hours,
  - Cut down on exercise,
  - Try to rest often in shady areas,
  - Protect yourself from the sun by wearing a wide-brimmed hat and sunglasses, and by putting on sunscreen.

Source: CDC 2003

6.2.1 Fans

Used appropriately, electric fans can help reduce heat stress. However, when used inappropriately, electric fans can exacerbate heat stress. Fans do not actually cool the air. As long as the air temperature is less than an individual's skin temperature, moving air can decrease heat stress by increasing the exchange of heat between the skin surface and the surrounding air, and by increasing the rate of evaporation from the skin (U.S. EPA 2006). If the dry bulb temperature is higher than 35ºC, the hot air passing over the skin can make an individual hotter. When the weather is very hot and dry, because of the limits of conduction and convection, using a fan alone when body index temperatures exceed 38ºC actually increases heat stress. When the temperature is more than 35ºC and the relative humidity is 100%, air movement can make an individual hotter. Thus, fans need to be used with caution and under specific conditions. Generally, use of fans should be discouraged unless they are bringing in significantly cooler air.

6.3 Community Level Responses

Community involvement is critical for the timely dissemination of information and for ensuring the health and safety of particularly vulnerable individuals. This can start with educational campaigns before the heat wave season begins. Where medical care is generally available, a coordinated response can be developed across ambulance and emergency services, hospitals, and other organizations providing care. The specific organizations to be included will depend on the medical care infrastructure. For example, in the US, fire departments are often called when there is a medical emergency.

An agency should be designated with authority to coordinate response activities and disseminate information. For example, in Queensland, Queensland Health is the lead agency, coordinating activities by the Department of Emergency Services, Queensland Police Service, the Bureau of Meteorology, Workplace Health and Safety, Education Queensland, Disability Services, Queensland Transport, and the Department of Energy (Queensland Government, 2004). See also section 8.4.1.3.

At a minimum, public officials and employers should:

- Inform the public of the anticipated heat wave and how long it is forecast to last;
- Communicate clear messages of the dangers of heat waves, emphasizing that health protection is the first priority. Where possible, postpone outdoor or sporting activities during the heat of the day, including at schools. Work with utilities to prevent suspensions of water and electricity service;
- Inform care-givers and those responsible for particularly vulnerable populations of the risks and appropriate responses. Additional emergency medical personnel may be assigned to address any increase in demand for services. Cooling centers can be opened to provide relief. Transportation for the most vulnerable can be provided to cooling centers;
- Provide access to additional sources of information, such as media broadcasts, toll-free numbers, websites, hotlines to report concerns about individuals who may be at risk.

In preparation for a heat wave, public agencies, health and social care providers, and employers can:

- Assess which individuals are at particular risk and identify what extra help they might need. Elder adults living alone are likely to need at least daily contact, whether by care workers or volunteers. People with mobility or mental health problems, who are on certain medication, or living in accommodation that is hard to keep cool, will probably need extra care and support.

Box 6.3

Philadelphia Hot Weather-Health Watch/Warning System

The City of Philadelphia and other agencies and organizations institute a series of intervention activities when a heat wave warning is issued. Television and radio stations and newspapers are asked to publicize the oppressive weather conditions, along with information on how to avoid heat-related illnesses. In addition, these media announcements encourage friends, relatives, neighbors, and other volunteers ("buddies") to make daily visits to elderly persons during the hot weather. These buddies are asked to ensure that the most susceptible individuals have sufficient fluids, proper ventilation and other amenities to cope with the weather.

A "Heatline" is operated in conjunction with the Philadelphia Corporation for the Aging to provide information and counseling to the general public on avoidance of heat stress. The Heatline telephone number is publicized by the media and by a large display seen over much of the center of Philadelphia.

When a warning is issued, the Department of Public Health contacts nursing homes and other facilities boarding persons requiring extra care to inform them of the high-risk heat situation and to offer advice on the protection of residents. The local utility company and water department halt service suspensions during warning periods. The Fire Department Emergency Medical Service increases staffing during warnings in anticipation of increased service demand. The agency for homeless services activates increased daytime outreach activities to assist those on the streets. Senior centers extend their hours of operation of air-conditioned facilities during warning periods.

Box 6.3 provides an example of the interventions used in the Philadelphia system (Kalkstein et al. 1996).

Table 6.1 compares the intervention activities between Philadelphia and Toronto. It is clear that coordination between the various stakeholders is important in these programmes, along with outreach to vulnerable populations, such as the homeless. In some cases, a list of high-risk individuals has been developed. If resources are restricted, some communities have identified the areas where most of the vulnerable people live. A number of utilities suspend electricity disconnections during a heat wave, thus providing necessary utility service to non-paying customers during the worst of the heat wave.

Table 6.1 Summary response and intervention elements in Philadelphia and Toronto

Program elements	Phila-delphia[a]	Toron-to[b]
Prediction		
Ensure access to weather forecasts capable of predicting heat wave conditions 1-5 days in advance	√	√
Risk assessment		
Coordinate transfer and evaluation of weather forecasts by heat wave program personnel	√	√
Develop quantitative estimates of the heat wave's potential health impact	√	√
Use broad criteria to identify heat-attributable deaths	√	√
Develop information on high-risk individuals	√	
Develop an accessible record on facilities and locations with concentrations of high risk individuals	√	√
Notification and response		
Coordinate public broadcasts of information about the anticipated timing, severity, and duration of heat wave conditions and availability and hours of any public cooling centres	√	√
Coordinate public distribution and broadcast of tips on how to stay cool during a heat wave and heat exposure symptoms	√	√
Operate phone lines that provide advice on staying cool and recognizing symptoms of excessive heat exposure, or that can be used to report heat-related health concerns	√	√
Designate public buildings or specific private buildings with air-conditioning as public cooling shelters and provide transportation	√	√
Extend hours of operation at community centers with air-conditioning	√	
Arrange for extra staffing of emergency support services	√	
Directly contact and evaluate the environmental conditions and health status of known high-risk individuals and locations likely to have concentrations of these individuals	√	√
Increase outreach efforts to the homeless and establish provisions for their protective removal to cooling shelters	√	√
Suspend utility shut-offs	√	√
Reschedule public events to avoid large outdoor gatherings when possible	√	
Mitigation		
Develop and promote actions to reduce effects of urban heat islands Not evaluated		

Source: US EPA 2006

6.4 Outdoor Workers

The International Labor Organization and others have established standards for occupational heat exposure. The basis of the regulations is to maintain core body temperature below 38ºC. Because core body temperature varies with level of physical activity, recommended exposure levels are often categorized by work load, as shown in Box 6.4.

Box 6.4

Recommended Threshold Limit Values for TLU Heat Exposures

PERMISSIBLE HEAT EXPOSURE THRESHOLD LIMIT Work Load* VALUES

Work/rest regimen	Light	Moderate	Heavy
Continuous work	30.0°C	26.7°C	25.0°C
75% Work, 25% rest, each hour	30.6°C	28.0°C	25.9°C
50% Work, 50% rest, each hour	31.4°C	29.4°C	27.9°C
25% Work, 75% rest, each hour	32.2°C	31.1°C	30.0°C

Values are in °C, WBGT (wet bulb globe temperature)

These TLV's are based on the assumption that nearly all acclimatized, fully clothed workers with adequate water and salt intake should be able to function effectively under the given working conditions without exceeding a deep body temperature of 38°C. They are also based on the assumption that the WBGT of the resting place is the same or very close to that of the workplace. Where the WBGT of the work area is different from that of the rest area, a time-weighted average should be used.

The TLVs in Box 6.4 apply to physically fit and acclimatized individuals wearing light summer clothing. If heavier clothing that impedes sweat or has a higher insulation value is required, the permissible heat exposure TLV's must be reduced.

Most heat stress in outdoor workers can be prevented by (1) engineering controls, such as general ventilation, evaporative cooling, and spot cooling; (2) changing work practices, such as providing plenty of drinking water; (3) scheduling heavy work during the cooler parts of the day, or reducing the physical demands during the hottest part of the day; (4) alternate work and rest periods, with rest periods in a cool area; (5) wearing appropriate clothing; and (6) employee education of the hazards of heat stress.

Box 6.5 provides tips from the US Occupational Heath and Safety Administration on reducing heat stress in employees (OSHA, 1999). These are similar to the advice provided to the general public.

Box 6.5

Tips on reducing heat stress

Encourage workers to drink plenty of water about 1 cup of cool water every 15 to 20 minutes, even if they are not thirsty and to avoid alcohol, coffee, tea and caffeinated soft drinks that dehydrate the body.

Help workers adjust to the heat by assigning a lighter workload and longer rest periods for the first 5 to 7 days of intense heat. This process needs to start all over again when a worker returns from vacation or absence from the job.

Encourage workers to wear lightweight, light-colored, loose-fitting clothing. Workers should change their clothes if they get completely saturated.

Use general ventilation and spot cooling at points of high heat production. Good airflow increases evaporation and cooling of the skin.

Train first-aid workers to recognize and treat the signs of heat stress and be sure all workers know who has been trained to provide aid. Also train supervisors to detect early signs of heat-related illness and permit workers to interrupt their work if they become extremely uncomfortable.

Consider a worker's physical condition when determining fitness to work in hot environments. Obesity, lack of conditioning, pregnancy, and inadequate rest can increase susceptibility to heat stress.

Alternate work and rest periods, with rest periods in a cooler area. Shorter, more frequent work-rest cycles are best. Schedule heavy work for cooler times of the day and use appropriate protective clothing.

Monitor temperatures, humidity, and workers' responses to heat at least hourly.

Source: OSHA, http://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_4.html#5

6.5 Summary

Table 6.3 summarizes public health measures promoted in the US and European heat wave and health warning systems, with their level of implementation (Kovats and Ebi 2006). Clearly there are a wide range of interventions that can be implemented to reduce the health risk of heat waves. However, the local context, including human and financial resources, cultural practices, and other factors, will determine which interventions would most likely be effective, and how the information would best be communicated.

Table 6.3 Public Health Measures in US and European HHWS

Measures, Strategy	Level of Imple-mentation *	Comments
Media announcements (radio, television)	+++	Provide general advice on heat stress avoidance to general public
Bulletin or webpage	+++	May be restricted access, to relevant professionals or accessed by anybody
Leaflet	++	General advice, and advice for nursing home managers. Often distributed at beginning of the summer via health centers, and places where vulnerable people may be.
Telephone help-line	++	Either a dedicated telephone service is opened (e.g. Heatline in Portugal) or people are encouraged to phone a pre-existing general health advice line (e.g. NHS Direct in the U.K.)
Opening of cooling centers	++	Some evidence that cooling centers not used by high-risk individuals, but used by low-risk individuals
Alert to hospital emergency rooms, ambulance services	+	Used to improve operational efficiency (e.g. if needed to deploy extra staff). Needs to be based on local information and carefully evaluated.
Home outreach visits to vulnerable persons	+	Important but usually expensive. Use pre-existing networks of volunteers (e.g. Buddy system in Philadelphia), or professionals (e.g. social workers). Requires some registry of vulnerable people.
Evacuation of vulnerable persons from their homes to cooling centers	+	Using a registry of vulnerable people, who are visited at home, and evacuated, if necessary
Outreach to homeless	+	High-risk group in southern U.S. (11 homeless people died in heatwave in Phoenix, July 2005)
Electricity companies cease disconnection for non-payment	+++	Utility companies have initiated and financially supported HHWS in the US. Most important where population relies heavily on air conditioning (as in the US)
Water companies cease disconnection for non-payment	+	
Fan distribution	++	Fans are effective when they circulate cooler air, but not about temperatures ~37ºC
+ rarely implemented, ++ often implemented, +++ very often implemented		

Source: Kovats and Ebi 2006

7. EVALUATION OF HEALTH WARNINGS AND HEALTH PROTECTION MEASURES

7.1 What is evaluation?

This chapter will focus on the evaluation of the heat/health warning system and not on the evaluation of other parts of a heat wave plan or policy (e.g. housing or treatment). Also discussed will be some of the general principles of evaluation of health interventions and the common methods used. At the end of the chapter some general qualitative criteria against which an HHWS can be assessed are proposed.

Evaluation is the process of judging the worth or value of something (Wimbush and Watson, 2000). In general there are two types of evaluation, namely: process and outcome evaluations (Table 7.1). An example of an outcome evaluation is when a public health intervention is evaluated based on estimates of the lives saved (premature deaths avoided) and other criteria such as acceptability or reduction of health inequalities. For a process evaluation, the emphasis is placed on the "working parts" of a system that lead to the initiation of an intervention.

Notwithstanding the type of evaluation under consideration, in general, evaluation should aim to:

- Ensure that the HHWS is having its intended benefits to the health of the target population (effectiveness)
- Determine whether the HHWS is cost-effective (efficiency)
- Establish whether the HHWS is acceptable to the target population (humanity).

The key stages of an evaluation are outlined in Box 7.1

Box 7.1

Evaluation framework

Evaluation should include the following steps (Morgan 2006)

1. Clear rationale and overview of the purpose of the evaluation
2. Consideration of methods required to evaluate the system or programme
3. Clear set of aims and objectives of the system and for the evaluation
4. A list of indicators required to measure effectiveness of the system
5. Clarify how the results of the evaluation will be used and explicit plans to disseminate and act on the results of the findings.

The stakeholders of an HHWS can have different reasons for undertaking an evaluation, and these need to be addressed when defining the objectives of the evaluation. For example, a policy maker may be most concerned with cost-effectiveness of the system, health practitioners may be most concerned that people are working effectively, and community organisations will want to know that the warnings are reaching the intended vulnerable individuals.

It is important to involve all stakeholders while developing and implementing the warning systems. The stakeholders' perspective will help also define the aims and objectives of the evaluation of the HHWS. It is also important to consider evaluation and monitoring when the

HHWS is set up so that the appropriate information can be collected. It is often difficult to do this retrospectively.
Monitoring and review systems should be set up and continue as long as the HHWS is operational. Monitoring for routinely recorded data about inputs and outputs in the HHWS, including any agreed performance standards should also occur. It may also be helpful to collect baseline data (e.g. about the impact of heat waves in the population), so that a comparison can be made once the HHWS is operational. Sections 7.2 and 7.3 provide more detail on process- and outcome-based evaluations with the key characteristics and differences summarized in Table 7.1.

Table 7.1 Characteristics of outcome and process evaluations

	Outcome evaluation	Process evaluation
Objective	To assess the results/ impact/ outcomes of a programme/ intervention	To assess what goes on during a programme/ intervention
Research questions?	How many lives were saved/hospital admissions avoided by intervention/programme? What is the cost-effectiveness of the intervention?	What was quality of programme delivery? Did the warnings reach health and social care staff and the intended target group(s) in the community? How were the warnings received? What contextual factors are important in facilitating or hindering issuing the warnings? What are the possible unintended consequences of the HHWS?
Methods	Quantitative, Qualitative Formal assessment of epidemiological data such as daily mortality or of intermediate end points such as changes in knowledge or behaviour.	Qualitative. Data collected by interviews, interviews face to face with key participants, providers, telephone surveys. Contextual analyses
Limitations	Can be very difficult to identify to get data needed at the appropriate resolution. Can be difficult to attribute any health benefit to the HHWS with confidence. Ethical issues for experimental studies, that is, cannot deny part of the population heat-health protection measures, unless there is real uncertainty about their effectiveness.	Need to identify key players in advance. Small numbers of people. Cannot provide definitive answers.

7.2 Process evaluations

Process evaluation is evaluation that concentrates on examining the process of an intervention. In the context of HHWS, this would focus on the operation of the warning system at all stages from the meteorological forecast, to issuing alerts to all the relevant institutions. It may also include the activities (interventions) that are linked to heat wave alerts and undertaken by health and social care professionals. The process evaluation determines if all actors have an understanding of their roles and responsibilities and are able to undertake them during a heat wave. It would also identify any barriers to communication or cooperation that exist within the system. Successful interventions require information and data sharing between the relevant health and meteorological agencies. A key barrier in effectively implementing a warning system is often the lack of clear lines of communication between individuals and institutions (see Chapter 5).

A process evaluation of any complex system is recommended. HHWS often involve quite a complex information cascade, and it is important to check that every person who should be doing something understands their role and responsibilities. It may be that key messages only reach senior staff and not the persons (e.g. nurses, community workers) who are actually required to take action.

It is also important to know if the "acute measures" linked to a warning are implemented in a timely and appropriate manner. This is particularly important for heat wave interventions as heat waves are short lived and activities should be implemented immediately or within 24 hours.

It is important that the result of any evaluation is disseminated to the participants in the HHWS. Regular process evaluations will build awareness and confidence in the system.

Key process evaluation questions include:

- What is the frequency and type of heat alerts over a specific period,
- What is the effectiveness of the cascade of information to health and related professionals,
- What actions were taken in response to the various levels of alert and the barriers and facilitators to action,
- What were the outcomes and how did these differ across the "high risk" or targeted groups.

For persons responsible for actions in the HHWS key process evaluation questions include:

- Who possesses awareness and knowledge of the written Heat Wave Plan?
- Is HHWS delivered as widely as intended?
- Is there good communication between agencies?
- Are role and responsibilities understood?
- What are barriers to implementing relevant activities? [financial, information, etc].

A good training exercise is to conduct a desk-top simulation exercise where key people role play as if a heat wave had actually occurred. This helps people to understand their roles and responsibilities. Evaluations have often found that there was need to define role and responsibilities, as well as improve inter-agency cooperation.

7.3 Outcome evaluations

The outcome evaluation is the assessment of the effectiveness of the HHWS in terms of heat deaths avoided. Evaluation of intermediate endpoints (such as changes in behaviour) can also be undertaken.

Such evaluations generally focus on mortality as the outcome measure, although other endpoints could be used (e.g. emergency hospital admissions, contact with primary care

services or help lines). Outcomes must be shown to be sensitive to hot weather in the intended population and this requires complex epidemiological analysis.
The epidemiological methods for quantifying the temperature-mortality relationship are described in the climate and health literature. It is possible to compare this relationship (the slope) before and after the introduction of a HHWS. Population mortality should become less sensitive to temperature extremes over time. However, there are difficulties in attributing this change to the HHWS as other factors (e.g. widespread air conditioning) may have also changed over time. Analysis of deaths on hot (heat wave) days with and without warnings during a single summer may also provide some indication of the effectiveness of the HHWS, however there are possible ethical issues associated with this approach. A third approach is to more formally compare interventions in different areas. It would be unethical to provide no heat-health protection in a given area. However, given the level of uncertainty around effectiveness for specific interventions, it would be appropriate to compare different strategies in different areas within a given city or district, and even to randomly allocate interventions at the community level.

7.3.1 Evaluating the "trigger" indicators

There are a variety of statistical techniques to test the robustness of the weather-health predictive model, as well as the meteorological forecasts themselves. In all cases, the model should be tested on independent data (i.e. years not originally included in the model). The test should not include years when the HHWS is operational as this could alter the original weather-health relationship.

For HHWS, which focus on the short range (0 – 3 days) one precondition for an effective system is that the indicator that is used for triggering the warning can be forecast accurately. A skilful forecast of the warning indicator (e.g maximum temperature) will minimise the number of false alarms and missed alarms and so the confidence in the HHWS will be high. The forecast error of a numerical weather prediction model depends on the model itself (model dynamics and physics), on the weather situation, on the region for which the forecast is made and on the parameter that is forecast as well as on the lead time of the forecast. Air temperature is a surface parameter with a relatively high forecast accuracy. The forecast error is higher for dew-point temperature, wind speed and radiation. With increasing lead time the accuracy of the forecast decreases.

It can be therefore expected that the accuracy of heat warnings that depend on air temperature as the trigger meteorological parameter for lead times up to 3 days is quite high. Forecasting heat indicators that require also dew-point temperature, wind speed and or radiation as input have a lower forecast accuracy. Heat warnings based on such indicators should therefore not be given with lead times longer than 48 hours.

7.4. Public warnings and advice

As outlined in Chapter 5 a communication and public education strategy is an essential part of any warning system. Public health messages should be disseminated to all age and risk groups to increase awareness of symptoms of heat-related illness. In the US, the most susceptible individuals are socially isolated, elderly, and may have a mental illness or disability that causes cognitive/behavioural problems. An understanding of knowledge, attitudes and perceptions about "thermal behaviour" is needed before the most appropriate messages can be developed and targeted.

Qualitative research methods are required to address the effectiveness of methods of communications as well as the specific message. Focus groups or face to face interviews have been used to elicit useful responses. Investigation of the knowledge attitudes and behaviour of high risk groups and their carers can focus on questions of their understanding

of the risks associated with heat waves and the needed responses, as well as their experience of actual heat wave measures. It may be that weather perceptions are different in older adults, and the very elderly. As outlined in Chapter 5 this relates to the concept of different "risk signatures".
Some specific research questions relating to communication of messages and information include:

- How do people currently access and use weather information in their day to day lives?
- What are the key differences for different age groups, and men and women?
- How do people value, and how might they use, precise 'early warning' information on heat waves?
- What currently affects their behaviour during heat wave (such as financial issues, morbidity that limits movement, etc).

If a programme of research on the effectiveness of public warnings and advice is planned as part of any evaluation exercise, it should be borne in mind that many persons at high risk of heat-wave related mortality are less likely to participate in focus groups or interviews, either by phone or in their own homes. Therefore, care should be taken how study participants are selected, to ensure that the sample is not too heavily biased towards low risk individuals. Ethical approval should be obtained before interviewing people at home, especially vulnerable individuals. Some of the issues and outcomes associated with surveys of the public perception and response to heat warnings are outlined in Sheridan (2007).

7.5. Criteria for Evaluation of a HHWS

The following criteria are suggested for the evaluation of heat warning systems. These criteria can be used for planning, implementing, and on-going evaluation to promote the best use of public resources through development of effective and efficient HHWS.

Simplicity:

The simplicity of a system refers both to its structure and ease of operation. HHWS should be as simple as possible while still meeting objectives. Factors to consider include:

- Type of information required to issue a warning,
- Number of people and agencies involved in issuing a warning,
- Time spent maintaining the system,
- Time spent issuing a warning.

Acceptability:

The acceptability of a system reflects the willingness of individuals and organizations to participate in the system. Factors to consider include:

- Interaction between agencies,
- Participation of agencies other than that issuing the warning,
- Completeness of response in participating agencies.

Timeliness:

Are the warnings timely with respect to the different response activities? Are there any delays in the steps of the HHWS.

Sensitivity:

The sensitivity of the warning is the number of times a warning is issued and the forecast meteorological conditions actually occurred. One should also consider how often a warning was not issued, but adverse meteorological conditions actually occured?

Specificity:

The specificity of the forecast (the prediction of heat-attributable mortality) should be estimated, as well as the accuracy of the meteorological forecasts on which they depend, in order to avoid false positive forecasts of heat wave mortality, which will undermine the credibility of the system.

7.6 Summary

HHWS are implemented at the local level, and therefore vary widely in structure, partner agencies, and the specific interventions that are deployed during a heat wave or for the summer season. Activities related to HHWS may also change from year to year in response to events, and the changing priorities of partner agencies. Heat waves are rare events and the impact of each heat wave is different. Heat-related deaths are also non-specific and difficult to identify. For all of these reasons, HHWS are extremely difficult to evaluate in terms of outcomes, in the formal public health sense. There are many types of evaluation and it should be acknowledged that different stakeholders may have different requirements for the evaluation of a system. Further stakeholders should be involved in evaluation and the objectives and methods of evaluation should be incorporated into the set up of the system.

8. DEVELOPMENT OF INTRA SEASONAL HEAT/HEALTH PLANS

This chapter discusses the pre-season and intra-season considerations that might be employed to maximize the benefits of a Heat/Health Plan. Also discussed is the possibility of using climate prediction models and medium-term weather forecasting models to provide health authorities with some advance notice of a heat wave event or indications as to how many heat/health events or possible severity of events are likely in the current season. This latter advice is analogous to early season tropical cyclone (hurricane) predictions for emergency agencies.

8.1 Planning for Next Summer

Planning for the next summer should not only consider heat-waves but should take into consideration a number of risks that are higher in summer time: such as an increased risk of food and water-borne diseases; risks associated with recreational waters; risks associated to tourism and migration; potential water scarcity and risks to health from excessive sun exposure.

A combination of summer and heat-wave activities seems useful particularly in countries where hot weather is expected during the whole summer. This may be increasingly applicable to northern European countries as a result of global climate change.

A precondition for the implementation of effective heat plans and heat-wave prevention is co-operation between institutions as outlined in previous chapters. Planning with the meteorological institutions and health and social services is essential. This includes the establishment of information flows and decisions on responsibilities. In countries where heat plans exist, this is normally addressed. In countries where no heat plan exists, although there is in most countries a meteorological component of warning, no decision-making structures might be available. Including heat plans into national disaster preparedness planning might be advisable but this depends on the countries' requirements. This issue needs to be explored at a country level, due to the differences in responsible authorities and administrative structures.

Health system and social service delivery planning are essential. Activities include:

- Planning of summer holidays and sufficient coverage of nursing staff in hospitals and nursing homes during that period;
- Contingency plans for well-trained staff to be available during heat alert periods and emergency situations;
- Curricula for health professionals training in relation to prevention and treatment of heat/health effects.

Exploring financial incentives and eventual legislation might be needed in some countries. The actual cost of heat prevention depends on the activities foreseen and the organization of the health system and collaborating sectors. Lack of funding and personnel as well as problems with communication are the most common barriers to the efficient implementation of heat prevention activities.

8.2 Climate Prediction Models and Heat/Health Plans

Heat/Health Warning Systems commonly employ the use of weather forecasts of expected meteorological parameters such as temperature, humidity and wind speed with a time span that might give advance warning of up to about 5 days. Many systems work in the 12 to 48 hour timeframes but have an awareness phase at longer lead times where numerical guidance material suggests the possibility of heat waves with varying confidence. This section discusses the possibility of using longer period climate modelling to give longer lead times of the possible onset of a heat wave event.

8.2.1 Climate Prediction Models

There is a range of climate prediction models of sea surface temperatures (SST) available globally that are used by meteorological and other agencies to provide seasonal outlook products. Predictions of SST are key components of these seasonal climate outlook products. Many SST prediction models focus on key areas of the ocean such as the eastern equatorial Pacific. These seasonal outlook products give predictions about temperature and rainfall over the next period of time, often one to three months ahead. These outlooks use trends in regional sea surface temperatures, ocean circulations and longer term patterns in the atmospheric circulation such as the Madden Julian Oscillation (MJO) and persistent anomalies in the circulation. Such predictions over these time scales do not define specific dates for any specific weather events such as heat waves, but indicate the likelihood of the temperature and rainfall varying significantly from normal. The skill of these outlooks often varies seasonally and for different regions (Figure 8.1). Seasonal assessments of threats of natural hazards, including heat waves are an extension of seasonal climate outlook products (Figures 8.2 and 8.3), which are now routinely produced, based on climate models, by a range of organizations (Table 8.1).

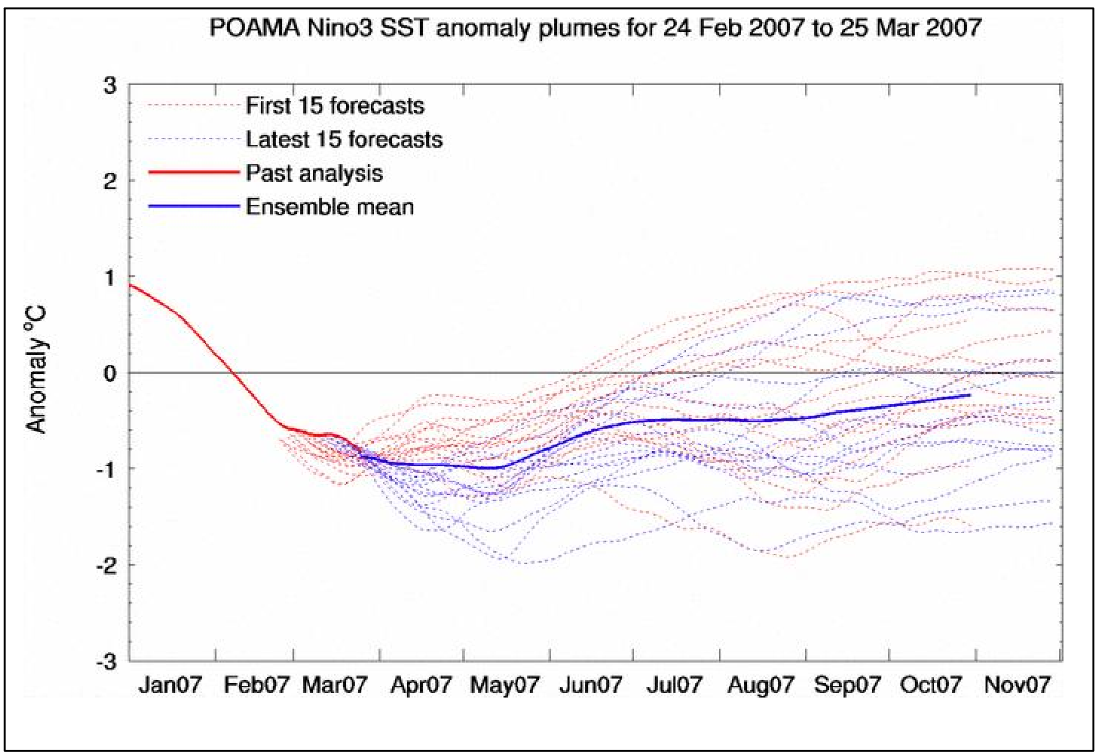

Figure 8.1 Example of one SST prediction model for the eastern equatorial Pacific Ocean

Table 8.1 (a) Officially designated WMO Global Producing Centres (GPC) and (b) Lead Centres of long range forecasts

(a) Officially designated WMO Global Producing Centres	
GPC	Web Address
Bureau of Meteorology (BoM), Australia	http://www.bom.gov.au/climate/ahead
China Meteorological Administration (CMA) / Bejing Climate Centre (BCC)	http://bcc.cma.gov.cn/en/
Climate Prediction Centre (CPC), NOAA, United States of America	http://www.cpc.ncep.noaa.gov/
European Centre for Medium-Range Weather Forecasts (ECMWF)	Forecast – http://www.ecmwf.int/products/forecasts/seasonal/
Japan Meteorological Agency (JMA) / Tokyo Climate Centre (TCC)	http://ds.data.jma.go.jp/gmd/tcc/tcc/index.html
Korea Meteorological Administration (KMA)	http://www.kma.go.kr/
Meteo-France	http://www.meteo.fr
Met Office (United Kingdom)	http://www.metoffice.gov.uk/research
Meteorological Service of Canada (MSC)	http://weatheroffice.ec.gc.ca/saisons/index_e.html
South African Weather Services (SAWS)	http://www.weathersa.co.za/
Hydrometeorological Centre of Russia	http://wmc.meteoinfo.ru/season
(b) Lead Centres of long range forecasts	
LC	Web Address
WMO Lead Center for Long Range Forecase Multi-Model Ensemble (LC-LRFEMME) Jointly coordinated by KMA and NOAA/NCEP	http://www.wmolc.org/
WMO Lead Center for Standard Verification System of Long Range Forecasts (LC-SVSLRF) Jointly coordinated by BoM and MSC	http://www.bom.gov.au/wmo/lrfvs/
Other leading centres providing global seasonal forecasts:	
Center for Weather Forecasts and Climate Studies/National Institute for Space Research (CPTEC/INPE), Brazil	http://www.cptec.inpe.br/clima/
International Research Institute for Climate and Society (IRI), USA	http://portal.iri.columbia.edu/
APEC (Asia-Pacific Economic Cooperation) Climate Centre (APCC), Republic of Korea	http://www2.apcc21.net/climate/climate01_01.php

Source: W. Landman South African Council for Scientific and Industrial Research

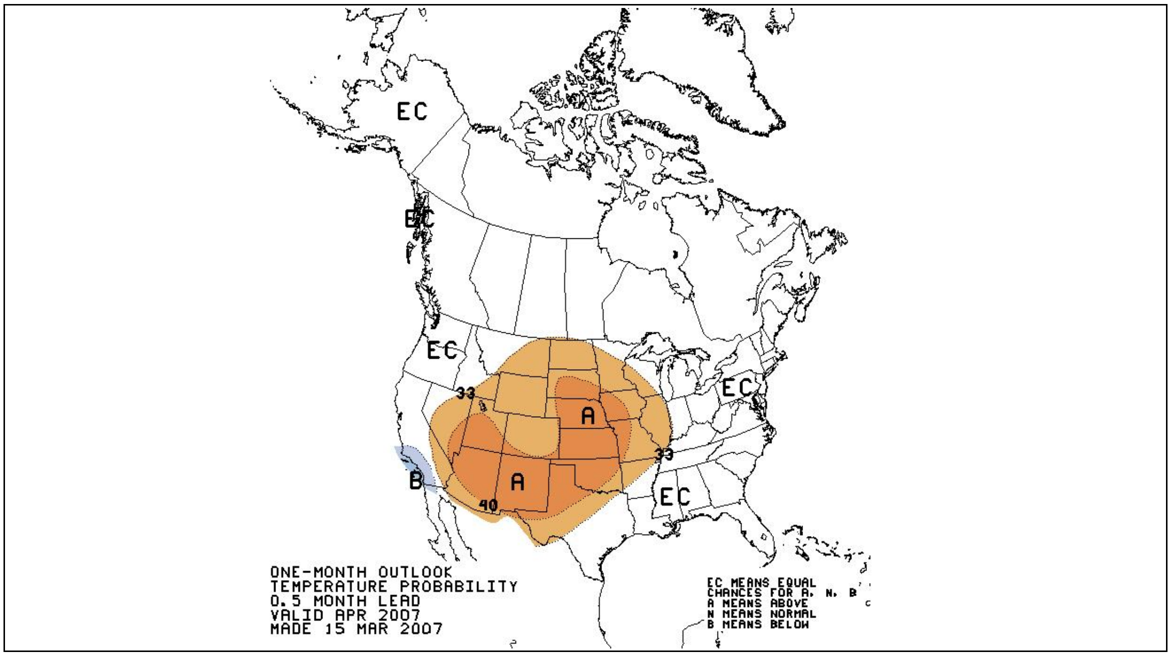

Figure 8.2 Example of US National Weather Service LDEO One month outlook on temperature probability and (below) ACMAD Temperature anomaly forecast for African region

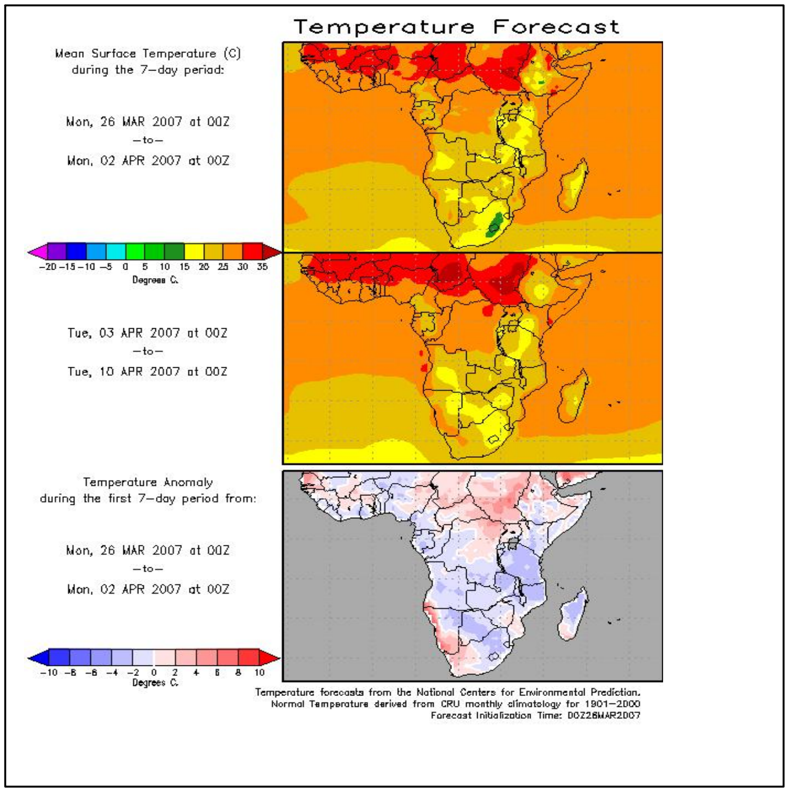

Figure 8.3 Temperature forecasts over Africa for 5 and 10 days ahead and the temperature anomaly(departure from mean) for 5 days ahead

Many of these assessments are done at a continental or regional scale while others focus on particular hazards or local regions. These assessments combine the climate predictions with other factors such as vegetation cover, the presence of long-term drought or flooding to estimate the relative likelihood of a hazard occurrence. Examples of these hazards include hurricanes, bushfires, frosts and floods as well as heat waves. Other products such as the ACMAD dekad (10-day) outlook also relate temperature and rainfall predictions to the probability of climate sensitive disease occurrence such as Rift Valley Fever and Malaria. These products are often developed with specific end users in mind, such as agriculture, fire fighting agencies or humanitarian aid agencies.

8.3 Using Climate Products With Heat/Health Plans

There is an opportunity for health authorities to use assessments of likely heat wave occurrence to make strategic preparations ahead of a season such as resource management for the possibility of a heat wave event and expand public awareness raising activities.

It should be noted that the probability of a heat wave event depends on the likely occurrence of both daily maximum and daily minimum temperatures above the long-term mean. While a product that indicates the probability of the maximum temperature being above normal provides some guidance, in some areas, perhaps in drought-affected regions, higher than mean maximum temperatures might be associated with below mean minimum temperatures. Also the short-term variability of temperature in a particular season might be different from the long-term average. Consequently an indication of the likelihood of above average temperatures might not correspond to an increased likelihood of heat waves.

There is also an opportunity for heat/health warning systems to incorporate the improved prediction skills of meteorological numerical prediction models that now exist with a range up to perhaps 7 to 10 days. The issuing of advice to health authorities at this range, without necessarily issuing public advice might assist the health authorities to prepare their resources and activate other components of their health plans to appropriate levels of preparedness. In particular advice might be available at this time scale to alert authorities to the likely duration of the heat wave. For example a slow moving anticyclone predicted by models will indicate a greater likelihood of a prolonged heat wave event.

8.4 National Heat Plans

Different health agencies have developed a range of Heat/Health plans, dependent on the significance of heat waves relative to other health concerns in their region of responsibility. The frequency of heat wave events in a region relative to normal seasonal heat might impact upon the importance placed upon heat/health warning systems compared to other measures.

8.4.1 Common features of effective plans

Effective plans have a range of common features. These include:

(1) A Heat/Health Warning System that has clear activation thresholds. Thresholds should set out what levels of action are to be initiated and who is responsible for each action. This includes the establishment of clear and reliable lines of communication. There may be one or more activation thresholds corresponding with either simple warning / no warning status or multi-tiered levels of raised awareness, alerts and warnings. The optimal HHWS should neither miss heat wave events or give false alarms.

(2) Effective public awareness campaigns that operate prior to each season and incorporate clear action statements that are repeated periodically through the season and particularly at the onset of a heat wave event.

(3) Effective cooperation between the relevant health agencies and providers to ensure that adequate resources are available and that health systems are not over-burdened.

(4) Clear intervention strategies that are understood by participating agencies and a supportive public. Examples might include the use of neighbours to check on those at-risk as a first line of action, followed by the intervention of health practitioners and paramedics at the home or location of the at risk person so that only those with health emergencies are transported to hospital. See chapter 6 for the range of interventions.

In the following subsections a brief history of the development of heat/health plans for a number of locations is presented in order to illustrate different features of various heat/health plans. A useful overview of HHWS typology for Europe is provided in Matthies et al. (2008).

8.4.1.1 Philadelphia, USA

Philadelphia was the first US City to introduce a heat/health watch warning system in 1997. In this system local city staff work with the National Weather Service to determine when a heat wave is imminent.

Prior to the development of the Philadelphia Hot Weather-Health Watch Warning System (PWWS), the National Weather Service had been issuing heat warnings based on a standard threshold of the Heat Index (Apparent Temperature). The PWWS introduced the method of Kalkstein (1996) involving air mass classification and correlation with mortality to improve the sensitivity of alerting in heat wave conditions.

Following the issue of an alert, the Philadelphia Health Department contacts news organizations with tips on how vulnerable individuals can protect themselves. People who do not have air conditioning are advised to seek relief from the heat in shopping malls, senior centres, and other air-conditioned spaces. The system also relies on local “Block Captains” appointed by the local city council who are notified and asked to check on elderly neighbours. Other elements include the use of field teams to maintain home visiting, the activation of a telephone-based service where nurses assist callers who might experience heat-related health problems, and a city-sponsored outreach effort that encourages the public to visit older friends.

Following its successful operation, similar tailor-made systems are progressively being implemented for the 50 to 60 cities in USA where there are over 500,000 population and a co-located local meteorological office.

8.4.1.2 Canicule Plan of France

The Canicule Plan of France includes a Heat/Health Warning System that is integrated into the four activation levels, which are:

Level 1: Seasonal vigilance, continuously activated from 1st June to 30th September;
Level 2: When the thresholds are to be reached within three days
Level 3: When the thresholds are reached;
Level 4: When the thresholds are reached and when the heat wave tends to be prolonged or when exceptional conditions are met (e.g. drought, electricity blackout).

The plan is centred on five pillars:

- "The setting in place of protection measures for people at risk in care facilities and institutions. These measures include:
    - Regular access to air-conditioned buildings as an effective answer to combat heatwave situations and the risks of hyperthermia for elderly people;
    - The installation of at least partial air-conditioning in all care establishments, homes of the elderly, residences and especially units of long duration care;
    - In establishments for aged persons, the testing of “Code Blue” alarms on the day before an event, together with staff training in crisis management;
- Identifying people at risk in the community and establishing mechanisms to notify these people through local councils and social services in the event of an alert being issued.
- The medical institute InVS monitors the forecasts received from Météo France and proposes an alarm if the thresholds are exceeded. Criteria of a qualitative

nature are also taken into account including other weather conditions, air pollution, and social events. Moreover, InVS notifies fire protection organizations (SDIS), Services of Medical aid Urgently (SAMU) and emergency services. InVS has the responsibility to inform the Ministry in charge of health, which informs the Prefects of the departments concerned for which an alarm has been issued. In these departments, the prefect decides on the measures to be adapted within the framework of the heat management plan.

- Homes for the elderly and hospitals have equipment and procedures adapted to the needs for the people at risk. Before the summer, the Prefects review the services of male care nurses in residence, associations and services of assistance to residents, the voluntary associations and check the cooling equipment used during the summer season.
- At the national and local levels, dissemination of information is undertaken, aimed at the general public, health professionals, carers of infirm and elderly people and health establishments. During the summer, the population receives advice on protection from heat. The weather chart of vigilance issued by Meteo France each day at 6 a.m. and 4 p.m. takes into account the heat wave phenomenon. In the event of an alert, dissemination through radio and television of recommendations from the Ministry in charge of Health occurs.

8.4.1.3 Queensland Heat Plan

The Queensland Heat Plan in Australia adopts slightly different strategies to protect those at risk, who mainly live in Brisbane and adjacent south eastern Queensland. While a feature of the French Plan Canicule is the use of a network of General Practitioners to ensure that those at risk are notified, a feature of the Queensland plan is the use of ambulance paramedics to administer care and advice and only transport the serious cases to hospitals for further treatment.

The principles of the Queensland Health Plan are as follows:

- Capacity building of individuals and communities to self manage their response to heatwaves through strategies such as cooling their environment or accessing a cooler environment;
- Community involvement ensuring the health and safety of aged people and other people at risk of heat-related illness;
- Ensuring a high level of coordinated emergency medical care to Queenslanders during a heatwave;
- Summer preparedness campaigns to target public awareness about heat events, in addition to storm and cyclone events. This focuses on the principles of prevention and mitigation. Strategies include:
    - Advising the public of heat wave management strategies, via media releases as summer approaches.
    - Queensland Health and Queensland Ambulance Service developing leaflets with general heat care advice to health care professionals; (GP practices, pharmacies).
    - Queensland Health, Queensland Ambulance Service, Workplace Health and Safety and Education Queensland referring social care agencies (HACC, Meals on Wheels, etc.) to information available on the Queensland Health website - www.health.qld.gov.au. This information may be disseminated by social care staff and volunteers to their clients.

In this last point the heat plan includes a mechanism to provide information through the education department for schools and through occupational health and safety bodies for workers to alert them when it might be necessary to curtail school programmes or heavy work in outdoor or hot manufacturing environments.

The HHWS employs two stages of alert. A Heat Warning is issued if the Apparent Temperature is expected to exceed 36ºC in Brisbane for 2 days or more, and an “Extreme Heat Warning” if the Apparent Temperature is expected to exceed 40 º C in Brisbane for 2 days or more.

8.4.1.4 England Heat Plan

In the England Health plan, the core components include:

A Heat-Health watch system that operates from 1 June to 15 September, based on forecasts from the UK MetOffice that trigger levels of response from the Department of Health and other bodies. Advice and information is issued by the Department of Health direct to the public and to health and social care professionals, particularly those working with at risk groups, both before a heat wave is forecast and when one is imminent. Identification of individuals most at risk by primary care teams and social services is also undertaken. These people would have priority in receiving advice on preventative measures and possibly assessment for extra care and support during heat waves. Involvement of available help from the voluntary sector, families and others to care for those most at risk is also encouraged. This is determined locally, based on existing relationships between statutory and voluntary bodies. The use of media to disseminate advice to people quickly, before and during a heat wave is emphasized. The plan outlines responsibilities of participants at each of the four levels – Awareness, Alert, Heatwave and Emergency. Details on the England Heat Plan can be found through the UK Department of Health: http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_114430

8.5 Heat Plan Relevant Research Projects

A number of research projects have assisted with the understanding of heat/health relationships and the development of the components of Heat Plans across Europe. Because of their importance for advancing the understanding of the association between heat (and cold) and health and the development of policy responses to extreme heat events a summary of these projects is presented in Box 8.1.

Box 8.1

Major Research Projects Related to Science and Policy of the Health Effects of Extreme Climate Events Including Heat

Climate Change and Adaptation Strategies for Human Health (cCASHh)
cCASHh investigated the ways in which climate change affects health by carrying out a combination of impact and adaptation assessments for a selection of climate-related health outcomes namely heat and cold; extreme weather events including floods; infectious diseases transmitted by insects and ticks and infectious diseases transmitted in the water supply or through food (waterborne and foodborne diseases). cCASHh provided "now and how" strategies for health threats from climate change. The analysis of the health impacts of the European 2002 floods and 2003 heat-wave assisted especially with the design of new policies and the improvement of measures to address morbidity and mortality due to flooding and heat-waves. cCASHh also noted that improvements are not taking place quickly enough in those risk areas where no recent disasters or emergencies have occurred therefore levels of awareness and preparedness are low. A major conclusion of the cCASHh project was that any comprehensive long-term strategy for minimizing the risks associated with global climate change requires the combination of planned adaptation (now and how) and mitigation of climate change. Further international burden-sharing is needed to distribute the costs of adaptation according to the vulnerability of countries to climate change (Menne and Ebi, 2006; WHO, 2005)

Assessment and Prevention of Acute Health Effects and Weather Conditions in Europe (PHEWE)
PHEWE investigated the association between meteorological variables during the warm season and acute health effects (mortality, hospital admissions) in 17 large European cities for the purpose of using understandings of the association between heat and health outcomes to develop preventive strategies. Specific issues investigated included health-related threshold levels of a range of weather variables, form of the weather dose- health response curve, latency time between weather exposure and effect, specific air masses associated with health effects and the interaction between weather and particulate matter or gaseous air pollutants. Experimental heat/health watch warning system were also set up for six of the 17 cities (Michelozzi et al., 2007). A number of results have been published from this project demonstrating clear geographical variations in the weather dose- health response relationship and the potential synergistic effects on health, of heat and air pollution, for example, Analitis et al. (2008) and Michelozzi et al. (2009).

Improving Public Health Responses to Extreme Weather Event (EuroHEAT)
The general aim of the EuroHEAT project was to improve public health responses to weather extremes and, in particular, to heatwaves. EuroHEAT reviewed the literature and administered a qestionnaire to health officials in charge of heat-health action plans in 2005 in order to establish the nature of existing heat-health action plans in Europe and to identify models of good practice for national/local preparedness planning. Major findings from the EuroHEAT project included: the adverse health effects of heatwaves are largely preventable and prevention requires a range of actions at different levels: from health system preparedness, coordinated with meteorological early warning systems to timely public and medical advice and improvements to housing and urban planning. An outcome of EuroHEAT was the production of a guidance for the development of heat-health action plans (Matthies et al, 2008) which are recommended to be developed and implemented at the national and regional levels in Europe to prevent, react upon and contain heat-related risks to health (Matthies and Menne, 2009; WHO 2009).

8.6 Governance of Heat as a Hazard

Responsibility for the issue of heat as a health hazard usually falls primarily with the government department of health, at either national or local level, depending upon the size of the country and the extent of areas where heat waves are a problem within a country. If separate initiatives concerning development of heat/health plans have occurred at a local level in several places within a country, then achieving a higher level of national consistency should be a preferred objective. Such coordination might come from either a national health agency, emergency management authority or perhaps from national bodies that are associated with the various heat/health plans. In some cases, a country's National Meteorological Service might assist in coordinating the meteorological data and forecasts required.

At the local level, hospitals, ambulance providers and medical practitioners might be the motivating stakeholders in developing heat/health plans, since the occurrence of heat waves will impact on their workloads. Advance notice of a heat wave occurrence will assist in resourcing hospitals and other care givers and will allow for greater preparedness ahead of the heat wave event.

National Meteorological Agencies contribute to the heat/health plans largely through the provision of meteorological data and forecast information that are used in the development and operation of the plans. In the developmental stages of a HHWS, climate data are used in conjunction with mortality data or similar indicators of adverse health impacts to develop thresholds.

Emergency Management Authorities provide a framework for the management of heat/health plans in relation to other natural and man-made disasters. They may ensure consistency of intervention strategies between responses to different disasters. These authorities might also allocate public (government) funding to support the development and maintenance of Heat/Health Plans in conjunction with preparation for other hazards.

8.7 Summary

Heat Plans are composed of a number of components including an alert system or HHWS which operates on the timescale of a heat wave event and a number of longer term components such as education, seasonal awareness and the development of workable intervention strategies. A number of Heat Plans have been developed at a variety of scales and for different countries. Consequently each Heat Plan in many ways is quite unique. That aside a fundamental imperative in developing a Heat Plan is the issue of heat governance, that is "who" has responsibility for heat as a hazard at the broad national or regional as we well as at the institutional level. Although HHWS, as components of Heat Plans, use weather forecast data at lead times of 3-5 days, improvements in seasonal climate forecast services and products offers the possibility of developing heat risk awareness at longer monthly and seasonal time scales.

9. LONGER-TERM INITIATIVES FOR MANAGING HEAT

9.1 Future Development of HHWS

As advances in science and technology are achieved, so will the development of HHWS advance. Amongst current operational HHWS the level of sophistication varies. Some HHWS rely on manual data feeds while others are semi- if not fully automated. With time and adequate resources, those agencies that run "manual" HHWS will gain access to the requisite technology to facilitate development of fully automated systems. Notwithstanding technological developments, human intervention will still remain a key component of HHWS. While technology will bring about improvements to data acquisition and flow and thus the technical development of HHWS, consensus decision-making by HHWS operators, stakeholders and end-users will remain essential to the effectiveness of HHWS now and into the future.

Scientific impediments to the effectiveness of HHWS are the reliability of meteorological forecasts and the robustness of the meteorological or biometeorological index threshold values used to trigger warnings.

If the last decade can be taken as a guide to the next, then major improvements in forecast accuracy, possibly out to 10 days, can be expected. Because heat waves are usually associated with stable atmospheric circulation regimes such as blocking, improvements in the forecasting of atmospheric circulation regime transition will assist immensely with the credibility of HHWS as far as the underlying meteorological science is concerned. Moreover ensemble forecasts of critical meteorological variables will help quantify the uncertainty associated with weather forecasts over a number of timescales.

The robustness of threshold values for triggering warnings is often dependent on the length of the historical climate and health record used to derive the threshold. More often than not it is the shortness of health records that compromises threshold robustness. To achieve greater confidence in the reliability of threshold values as predictors of inflection points in climate and health relationships, HHWS developers must work closely with the relevant agencies to secure daily meteorological and health data for as long a period as possible. Further, key players in both NMHS and health services should work closely together to ensure that data required for HHWS development is homogeneous and relevant. Surmounting the problems of forecast accuracy and threshold robustness are therefore essential if good science is to underpin the future development of HHWS.

With advances in human heat balance modelling and the availability of the requisite data for heat balance models on a routine basis, the incorporation into HHWS of complex biometeorological indices that attempt to portray the exchange of heat between a reference person and the ambient environment is a likely future development in some locations. There are a vast array of empirical biometeorological indices and a number of human energy balance models. A common characteristic of these is their non-universality such that they may not be transferable to a wide range of environments. However the development of a "universal comfort index" as has been attempted in the European Union COST730 project (http://www.utci.org/cost.php) may provide the possibility that many HHWS could, in the future, be based on a standard descriptor of heat stress. Future developments might also include adjustments of meteorological and biometeorological thresholds based on assumptions about intra-seasonal acclimatisation.

In some political and social contexts the unavailability of health data may be an over-riding factor that restricts the derivation of critical meteorological or biometeorological index threshold values and thus the development of HHWS. Consequently the HHWS scientific community must work towards developing a method for prediction of health-relevant meteorological thresholds in data poor areas. Achieving this scientific challenge will assist with the development of HHWS globally. In situations where there is basic meteorological information but no health data, a percentile based threshold (e.g. 90th, 95th) could be contemplated as a warning trigger value. Recent research has even indicated that thresholds as low as the 85th percentile for maximum temperature might be applied as a generic threshold (Honda et al., 2007).

Much remains unknown about the impact of the possible synergistic effects of heat and poor air quality on health. What is clear from research on this topic is that there may be no universal truism about heat, air quality and health. This is because the relative importance of heat or air quality for health outcomes during very hot weather may vary geographically. Notwithstanding the scientific debates surrounding this issue, a possible development could be the incorporation of air quality information in HHWS. However to achieve this, spatially and temporally integrated air quality, meteorological and health monitoring networks will need to be established.

9.2 Seasonal Forecasting

Seasonal forecasting refers to predictions of meteorological variables 10 to 90 days in advance. Such forecasts if they are reliable have the potential to assist in decision-making for public health responses to severe climate events (McGregor et al., 2006). This is because, for some locations, high levels of natural all-cause mortality at the summer weekly, monthly and seasonal timescales have been found to be associated with anomalous heat at the same timescales. Variations in intra-seasonal to seasonal mortality are most likely associated with summer climate variability because periods of anomalously warm weather have a fundamental effect on mortality through increasing, for example, the physiological risk factors associated with heat-related health outcomes. Based on this, advanced warning of forthcoming periods of anomalous hot weather might be possible. Already there are encouraging signs that fully coupled ocean-atmosphere multi-model predictions of summer temperature at the intra-seasonal to seasonal timescale are improving for areas that have a history of heat wave related problems. Accordingly the potential exists to incorporate seasonal climate information into public health sector decision-making. However for mutual benefits to accrue in the areas of the application of climate information in the public health sector, then enduring partnerships, based on a firm interdisciplinary knowledge base, will need to be built between the climate and health research and planning communities.

9.3 Urban Design

During periods of hot weather, nocturnal temperatures in urban areas may reach several degrees above their rural counterparts because of the heat island effect. As a result urban inhabitants will not benefit from night-time relief from heat.

The principal causes of the urban heat island (UHI) are the storage by day of solar energy in the urban fabric and release of this energy into the atmosphere at night, and the fact that evaporation from urban surfaces as a cooling process is very limited. Given this, strategies for tackling the root causes of the UHI and thus stressful night-time temperatures need to focus on controlling the absorption and release/escape of heat from the urban fabric and tipping the balance between the apportionment of available natural energy between heating and cooling of the urban atmosphere.

Policies designed to reduce the UHI may need to balance the need to manage heat at the building, neighbourhood and city scales, taking into account the nature of development (new versus existing) and be conscious of what is achievable in reality. Furthermore, because climate is changing this has implications for the planning and design of current and future urban developments from the local to city scale. Urban designers and planners need to acknowledge this and in doing so base design criteria on data that describes the current and projected future climate.

Because anthropogenic heat could become an important future source of extra heat in the urban atmosphere for some major urban areas, strategies focused on managing heat emissions and the location of heat ejection to the atmosphere from infrastructure will become an important issue for urban planners.

In developing UHI mitigation strategies, it must be borne in mind that the UHI is a city scale phenomenon and the outcome of the combination of the vast range of urban microclimates. Further, as the built components of the urban system occur at different scales (e.g. individual building to industrial park to major industrial zone) any physical alteration of these will have climate impacts at different scales. Consequently the link between urban heat island management policy and urban climate scale needs to be acknowledged (Table 9.1). Perhaps the best way forward is to think about ways in which climate at the individual building to neighbourhood scale can be managed, as focusing on these scales will eventually have a cumulative effect at the larger city scale. Effective strategies for local climate modification could include cool roofs, green roofs, planting trees and vegetation and cool pavements.

Table 9.1 The link between policy (London) and urban climate scales

Physical Scale	Policy Scale	Urban Climate Scale
Individual Building,/Street (façade and roof construction materials, design and orientation).	Building regulations and Building Control Urban design strategy Local Development Framework	1 – 10 m. Indoor climate and street canyon
Urban Design (arrangement of buildings, roads, green space)	Urban Design Strategy Area Action Plan Local Development Framework	10 – 1000 m. Neighbourhood scale, sub-urban variations of climate
City Plan (arrangement of commercial, industrial, residential, recreational and “natural” space)	Sub Regional Spatial Strategy Regional Spatial Strategy	1 - 50 km. City/Metropolitan scale, UHI form and intensity.

Source: GLA, 2006

9.4 Climate Change

Climate change is not only likely to bring about changes in the frequency and duration of heat waves in “core” heat wave regions but also an alteration of the geographical distribution of heat wave disasters. Heat waves could very well occur in locations where there is no previous history of occurrence because of the poleward shift of the mean summer maximum and minimum isotherm and an altered pattern of atmospheric and land surface moisture due to atmospheric circulation changes. This has implications for national governments in terms of reviewing their natural disaster response plans and the incorporation within these of national heat plans.

As society responds to climate change through adaptation, climate and health relationships may change. Consequently HHWS developers will need to continually review the sensitivity of their systems not only in response to societal adaptation but also short-term changes in social and health policy. Accordingly appropriate adjustments to system trigger points and also intervention strategies will be needed.

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