Heat Health Warning System Workshop
Atelier sur les systèmes de veille sanitaire en période de canicule

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Julie Dufresne was the principal technical organiser, and François Tessier helped with presentations and sound recording. Natasha Sincennes did much of the correspondence. Diane Blanchard provided administrative support.

The report was prepared by Madeline O'Connor, Joseph Shaykewich, and Marie-Ève Cardinal. Leah Kosatsky and Abel Kosatsky were proofreaders. The executive summary, prepared by Madeline O'Connor was translated into French by Marie-Ève Cardinal, and Marta Dikman.

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Our sponsors were The Montreal Public Health Department, with its partners the Quebec Ministry of Health and Social Services, Health Canada, the Canadian Public Health Agency, Environment Canada, and the Quebec Population Health Research Network.
Thank you to all our participants for their enthusiasm and for the expertise they shared.
Tom Kosatsky

FOREWORDS

Direction de santé publique de l'Agence de la santé et des services sociaux de Montréal

La Direction de santé publique de l'Agence de la santé et des services sociaux de Montréal a la responsabilité d'identifier les situations susceptibles de mettre en danger la santé de la population et de voir à la mise en place des mesures nécessaires à sa protection. L'impact des canicules sur la santé des personnes âgées, surtout celles qui souffrent déjà de maladies chroniques, est maintenant largement reconnu par la communauté scientifique. Parallèlement au développement d'approches préventives qui augmentent la capacité de la population à faire face à la chaleur, le réseau de santé publique en partenariat avec le milieu municipal et les services météorologiques a instauré un système de veille et d'avertissement qui vise à donner l'alerte et à apporter un soutien à la population vulnérable lors des vagues de chaleur estivale.

L'atelier sur les systèmes de veille et d'avertissement pour la chaleur accablante tenu à Montréal en octobre 2006 est arrivé à point, car il a réuni des experts d'Amérique du Nord et d'Europe confrontés aux mêmes problèmes et qui travaillent pour élaborer des solutions efficaces nécessitant la collaboration d'organisations provenant de plusieurs secteurs. Les présentations éclairantes et les échanges fructueux qui ont suivi nous serviront grandement à raffiner notre système et à identifier les domaines ayant besoin de recherches supplémentaires.

Nous remercions Tom Kosatsky et son équipe d'avoir organisé cet atelier et publié les actes qui en découlent. Nous remercions également tous nos collègues du Canada et des autres pays qui ont contribué au succès de l'atelier. La publication de ce rapport final sera d'une grande utilité pour les intervenants d'ici et d'ailleurs dans leur cheminement vers le développement des meilleures pratiques en matière de systèmes de veille et d'avertissement pour la chaleur accablante.

Montreal Health and Social Services Agency

The regional Public Health Department (of the Montreal Health and Social Services Agency) is responsible for identifying situations that could pose a health risk to the population and for ensuring that adequate protective measures are put in place. The impact of heat waves on the health of the elderly, especially those already suffering from chronic diseases, is now a well established problem. While efforts have focussed largely on the development of preventive approaches which increase the capacity of our population to cope with heat, the public health network and our municipal and meteorological partners have also implemented a warning system to sound the alarm and bring support to the vulnerable during summer's hottest days.

The heat health warning system workshop held in Montreal in October of 2006 was thus a very timely event, in that it brought together experts from North America and Europe who are confronted with the same problems and are working to elaborate efficient solutions that call for the collaboration of organizations from many sectors. The instructive presentations and the fruitful exchanges that followed have thus been most useful for us by facilitating our efforts aimed at refining our system and by identifying areas that need further research.

We are grateful to Tom Kosatsky and his team for organising the workshop and publishing this report of its proceedings and to all our colleagues from Canada and abroad who contributed to its success. The publication of this final report will be most useful to us in Montreal, and to a Quebec, Canadian, and international audience for the development of best practices in Heat Health Warnings.

John Carsley
Directeur par intérim de la Direction de la santé publique de Montréal

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Unité santé au travail et santé environnementale, Direction de santé

Ministère de la Santé et des Services sociaux
Direction de la protection de la santé publique

C'est avec une grande fierté que le Ministère a contribué au soutien de l'atelier Systèmes d'alerte canicule et santé, organisé par le docteur Tom Kosatsky et son équipe de la Direction de santé publique de Montréal.

Il n'est que de parcourir le présent rapport de cet atelier pour apprécier la haute qualité scientifique ainsi que la quantité impressionnante des présentations des conférencières et conférenciers, reconnus internationalement, qui y ont participé. Les divers aspects de la gestion des vagues de chaleur en milieu urbain ont été abordés de façon approfondie : systèmes d'alerte plus efficaces grâce à l'amélioration des prévisions météorologiques, interaction entre les services météorologiques et sanitaires, épidémiologie de la chaleur; surveillance de la morbidité et de la mortalité en fonction de paramètres météorologiques, physiologie et pathologie de l'exposition à la chaleur, et autres sujets.

On se souvient de la catastrophe survenue en France en 2003, alors qu'une canicule meurtrière avait causé la mort de milliers de personnes, surtout vulnérables ou âgées. Bien évidemment, une telle menace occupe, à l'approche de la période estivale, le plus haut rang des préoccupations des autorités de santé publique des pays « sur la ligne de front » des changements climatiques, dont le nôtre. La contribution de scientifiques versés dans les disciplines touchant les changements climatiques et leurs impacts sanitaires, réunis lors de cet atelier, est ainsi fort précieuse pour permettre aux autorités compétentes d'établir des stratégies optimales de prévention et de gestion de tels épisodes caniculaires.

Particulièrement intéressante à mon sens fut la suggestion des participants, au terme du colloque, à savoir qu'au niveau politique il serait important de considérer la chaleur comme un danger équivalent aux autres catastrophes naturelles, eu égard à ses impacts socio-sanitaires. Je crois que nous devrions ainsi accroître l'intégration entre la climatologie et la santé publique, à l'instar de plusieurs pays et villes importantes du monde qui ont commencé à intégrer dans leurs systèmes d'alerte canicule et santé (SACS) une combinaison des systèmes de surveillance météorologique avec les plans d'interventions en santé publique.

Enfin, nul doute que les résultats de ce colloque s'avéreront fort précieux aux fins des travaux de notre Comité sur la chaleur accablante. Formé de spécialistes de notre réseau de santé publique, avec la collaboration du Ministère, ce comité a notamment pour objectif de mettre à jour et partager les connaissances sur la problématique de la chaleur accablante, d'identifier des indicateurs météo et de vigie sanitaire pertinents, de développer et mettre à jour des outils de communication, et d'harmoniser les plans d'urgence entre les différentes régions concernées du Québec.

Encore une fois, toutes mes félicitations pour le franc succès de cet atelier scientifique, et mes plus sincères remerciements à toutes les personnes qui y ont participé, dans le meilleur intérêt de la santé de la population québécoise.

Guy Sanfaçon, Ph.D.
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Ministère de la Santé et des Services sociaux
Québec, le 18 mai 2007

Health Canada
Climate Change and Health Office

Various events of the past decade have highlighted the effects of climate on human health. Taken alone, the influence of climate on health could be considered of secondary importance. But in a context of increasing urbanization and population, aging populations, and expected temperature warming in many parts of the world, we cannot ignore the increasing risks from heat and heat waves. Past heat-waves in North America and Europe have also heightened the awareness of the need for effective measures to protect vulnerable segments of our populations. Canada, although a northern country, is not immune to these effects, particularly in metropolitan areas.

Heat health warning systems are increasingly looked upon by public health officials as a measure to assist in the protection of local populations. Sharing the early experience of cities from around the world that use these systems is critical in shaping the future approaches. Many warning systems are in use and what has worked to protect one community may not be effective for another. We need to better understand the strengths and weaknesses of the various approaches. This publication which summarizes the results of expert and stakeholder discussions makes an important contribution to our understanding of these approaches and provides public health officials with an invaluable resource for planning future interventions for addressing the needs of their citizens.

We are grateful to the experts and stakeholders who took the time to come to Montreal, Canada to share their knowledge and experiences with the implementation of heat warning systems. It is through the broad dissemination of their learning experiences that we will improve upon our practices aimed at protecting vulnerable populations from extreme heat events. I am confident that this publication will support the momentum and interest of public health authorities in Canada and elsewhere that are working to develop the needed responses to these new challenges.

Jacinthe Séguin
Climate Change and Health Office
Health Canada

Environment Canada
Meteorological Service of Canada

As the primary agency in Canada associated with weather and climate information, Environment Canada's Meteorological Service exists to provide Canadians with information to help reduce personal and property risks associated with weather. We recognise that heat, though pleasant most of the time, can occasionally place persons at serious risk. For this reason, we feel it is important that knowledge be acquired and shared and that appropriate tools be developed which would contribute to the improvement of the quality of life in such times of stress. We were therefore very glad to participate in this Workshop.

Denis A Bourque
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INTRODUCTION TO THE WORKSHOP

Tom Kosatsky
DSP Montréal/ Montreal Public Health

The Montreal Public Health Department, with its partners the Quebec Ministry of Health and Social Services, Health Canada, the Canadian Public Health Agency, Environment Canada, and the Quebec Population Health Research Network is pleased to present the proceedings of a technical workshop on Heat Health Warning Systems.

Following the devastating loss of life during heat waves in Chicago and Philadelphia, USA during 1995, and in much of Western Europe during 2003, many countries and cities have initiated, or are contemplating, partnerships among weather services, public health and civil protection authorities designed to foresee and prevent similar tragedies.

A variety of systems now in place are used by weather services and health authorities to warn the public that today's or tomorrow's hot weather puts health and even life in danger. Depending on the level of apprehended risk, and on the means which civic and public health authorities have available, warnings may be superseded by active interventions ranging from the distribution of water to the homeless, to opening municipal swimming pools, and the relocation of vulnerable persons to cooling shelters. The "Heat Health Warning Systems (HHWS)" which drive these warnings and interventions, are based on a mix of historical and practical considerations, and on theoretical understandings in the areas of meteorology, human physiology and epidemiology. This workshop has allowed the developers and users of these systems to share their knowledge and experience.

Objectives of the Workshop:
1. To review the various HHWS now in use as a guide for health and civil protection services interested in initiating or revising their own systems
2. To improve collaboration between HHWS partners
3. To recommend directions for the development of better HHWS

Under the auspices of the Montreal Public Health Department, an interactive 2-day workshop was convened in Montreal October 5 and 6, 2006, bringing together representatives of cities using various HHWS, cities contemplating using HHWS, and technical experts in the areas of meteorology, epidemiology, statistics, and civil protection. Participants came from Europe, the United States, Canada, and Quebec. Both the theory and the practical application of the various systems in place were reviewed. A particular emphasis was on the Quebec/Canadian context met through the involvement of national, provincial, regional and even local public health authorities and scientists in the fields of meteorology and public health response.

Format and results of the workshop

Since we are expecting this event to provide guidance about next steps to be taken in the field of HHWS, the workshop was conceived, and turned out to be, a relatively small highly interactive technical event with ample space for discussion and brainstorming. The results will assist the sponsoring bodies in planning and coordinating their future activities in this field, and will be shared with municipal authorities and national and international health, weather, and civil protection agencies worldwide. The results should inform guidelines for cities, countries, and public health authorities in determining and perfecting the optimal approach to calling heat-health warnings/ invoking emergency measures, given their particular needs.

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EXECUTIVE SUMMARY

A technical workshop on Heat Health Warning Systems (HHWS) was held in Montreal, (Quebec) Canada October 5-6, 2006. Thirty-five participants from six countries in Europe and North America, representing national, sub-national and municipal health, civil protection and weather services, the U.S. Environmental Protection Agency and several academic centres took part in the proceedings. The workshop was convened by the Direction de Santé publique de Montréal (Montreal Public Health). It was sponsored by Health Canada, the Ministère de la Santé et des Services sociaux (Quebec Ministry of Health and Social Services), Environment Canada, the Population Health Network of the Quebéc Health Research Council and the Public Health Agency of Canada.

Despite causing high levels of excess mortality around the globe every summer, extreme heat has rarely made international headlines. This changed in August 2003 with the European heat wave that claimed tens of thousands of lives. The impact of this event provoked a reaction from government officials in many countries, both in Europe and elsewhere. That the 2003 catastrophe was mediated by a combination of wide-spread urbanisation, an aging and increasingly vulnerable population and rising global temperatures have highlighted the need for a multi-sectoral approach to protect citizens from heat waves.

Many jurisdictions have mandated the collaborative efforts of climatologists, meteorologists, and public health officials to ensure that extreme heat events receive the same level of response planning as other extreme weather events. To this end, many countries, regions and municipalities have instituted meteorological surveillance systems which trigger a coordinated heat health response. The aim of this workshop has been to bring together scientists, civil protection and public health administrators and policy makers involved in developing these Heat Watch Warning Systems to examine and evaluate the criteria used for setting thresholds for action or response.

Participants shared lessons learned from the implementation and modification of their heat health warning systems and identified major strengths and weaknesses. Among prominent points emphasized was the need for interagency collaboration in the warning process. Although based on scientific evidence, systems must be tailored to the needs and environments of specific jurisdictions as well as to the resources available to them.

The workshop covered four main themes:

- Meteorology
- Health effects of heat
- Heat health warning systems
- Future directions

The first theme on meteorology aimed at educating developers and users of HHWSs as to the nature and precision of the weather data which meteorological services provide to them, as well as to innovations in forecasting which can improve the performance of HHWSs. A better understanding of weather and how it its forecast will enable developers and users to communicate to meteorological services the type and precision of forecast data they need, when they need it and how best to present it.

Experts in climatology described the role of national weather services in the development and evaluation of HHWS in their countries. The French system, where warning thresholds developed from the historical association between daily deaths and extreme high temperatures, is centered on a close collaboration between the weather and health services. The EPA funded the first U.S. heat warning system based on a synoptic model, which continues to operate in Philadelphia, and has developed guidelines for system evaluation. The EPA now focuses on outreach, education and intervention, has recently published a handbook on excessive heat events and is involved in studying urban heat island reduction measures. The weather service role in the German heat health warning system has been to develop a system based on biometeorological principles and to supply weather data and analyses to guide interventions by Lander (State) health authorities. In Canada, there is no national heat health warning system, and the national weather service provides weather data “products” for separate localities based on their needs.

An overview of local influences on weather for non-meteorologists was presented by a U.S. colleague, and representatives from the German, French, U.S. and Canadian weather services discussed how predictions are made. The limits of forecast accuracy and the range precision of various weather parameters were also presented, with most participants agreeing that accurate dew point prediction (a driver of warning triggers for many HHWS models) is a challenge. While forecasting techniques differ somewhat among agencies, improvements in forecasting over the past three to four decades have resulted in a gain in forecast accuracy of approximately one day per decade. However, forecasting is less accurate for specific weather parameters during extreme weather events.

“Ensemble” forecasting was presented as an innovation for future HHWS. Weather services using “ensemble” forecasts generate a set of results for 3-14 days ahead, using random perturbations of initial conditions and different numerical models. In Canada, 16 simulations have been run generating 16 solutions (models using greater numbers of simulations and higher resolutions of weather data are being tested), from which Environment Canada generates a “probability” that any specific weather parameter will occur (expressed as the number of simulations forecasting the weather parameter divided by 16). Administrators of civil protection agencies have requested climate information for lead times beyond 5-10 days in order to anticipate extreme weather events and assure that all necessary emergency response systems are in place. As an example of the value of seasonal forecasting, on May 1, 2003, a probabilistic forecast by the European Centre for Medium-Range Weather Forecasts for June-July-August predicted temperatures being in the upper tercile with fairly high probability in Southern Europe. This information was potentially very useful because one month before the onset of summer there was a strong indication of a very warm summer and it would be a good assumption that within this warm summer would likely be some very hot days. So one could use such a forecast to raise awareness and prepare responses. Incorporating the probability of extreme weather events into seasonal forecasts would be useful, not only for the health field, but also for other sectors such as agriculture and transportation.

The second theme focused on the health effects of heat: it centered on the development of the heat-health function and its implications for threshold setting. As a preamble, participants were reminded that any function linking heat and health needs to be described in terms of the target population specified, the health outcomes measured, and the weather parameters (temperature and others) considered; the possibility of cumulative effects (a function of the duration of heat episodes), prolonged effects, delayed effects, effect of when exposure occurs during the summer, as well as the effect of joint exposure to weather and air pollutants might also be incorporated into a heat-health function.

Various health outcomes have been or could be studied as a function of exposure to heat: among these are deaths related pathophysiologically to heat, all non-traumatic deaths, deaths beyond levels expected on the basis of long-term trends, and several health service indicators (emergency department visits, ambulance calls, health-information line calls, hospital admissions). Those targeted have included specific populations at risk (such as the elderly, sick, young children), workers, athletes, or everyone. Time frames considered have included the hot day itself, a brief interval between exposure and the health event (0 -2 days), short (within a week), mid-term (months), or long-term follow-up intervals. Procedures to estimate impacts include episode analysis or an overall temperature-response function (such as a time series) and can incorporate summer months only, summer plus a shoulder period, or data collected year-round. Analysis of heat wave episodes is dependent of their definition, for which there is no general consensus. An assortment of primary weather attributes (i.e., temperature, humidity, etc.), weather indices (i.e. apparent temperature), and overall conditions have been assessed in relation to health outcomes, as well as factors related to heat exposure such as air quality.

The evidence supports heat-stroke deaths as a minor contributor to overall heat-related excess mortality, while cardiovascular deaths tend to be the leading cause. The induction period from heat exposure to death is relatively brief, and evidence from several North American cities shows a non-traumatic mortality spike two days after the onset of high temperatures. There is some evidence, particularly when looking at dense, urban areas, that elevated night time temperature is a major factor in heat-related mortality. Virtually all city populations show increased daily mortality at temperatures below and above a city-specific optimal temperature, and this optimal temperature is higher with increasing average temperature, both by location (South versus North), and over time (with global rise in temperature). However, the mortality impact of both heat and cold have dampened somewhat during the last six decades, related perhaps to better population health status or to better insulated accommodations. Attempts to adjust the daily temperature-mortality function by taking into account air quality, humidity, and air mass type have produced inconsistent results, perhaps because of differences between cities, or methodological differences in parameterizing the factors considered.

Both heat episodes of longer duration and episodes earlier in summer have been associated with higher levels of mortality. That heat episodes later in summer are, less lethal than those earlier, once temperature is taken into account, suggests that acclimatization to heat may prevent mortality. While these hot day deaths are overwhelmingly seen in the elderly, chronic illness, particularly cardiovascular disease and psychiatric illness, is also an important risk factor. As for small children, physiologic studies have demonstrated that children younger than five-years old may be unable to meet needs for increasing cardiac output in the heat; and being left alone in a closed car has also been a factor in contributing to deaths in this age group. While research shows the magnitude of extreme temperatures tends to be amplified in urban heat islands, rural areas experience similar heat-related mortality effects. There appear to be differences in heat-related mortality between Europe and North America: elderly males in North America are seen as having the highest heat-related mortality risk, while in Europe females rank highest. A higher proportion of hot day deaths are coded as hyperthermia in the US compared to Europe. Additionally, a heat-related hospitalisation effect is seen in the U.S., but seemingly not in Europe, for reasons yet to be determined. It was noted that air conditioner ownership is more common in the U.S.

The pathophysiological effects of ambient heat, and their modification by humidity, sun exposure and wind were also explained. Heat adaptation, short (over days), medium (within season), and long term have been studied mainly using fit subjects in laboratory conditions and the validity of extrapolating this information to vulnerable populations is not yet completely understood. Modification of the heat response by personal behaviour (activity, hydration, clothing) has been found to be effective, but adaptive opportunity may be limited among certain groups, such as shut-ins or persons exposed to air conditioning. Because of these limitations, there is a potentially highly susceptible population that may need to be protected from moderate heat stress, and not just from the severe stress that causes heat stroke or heat exhaustion in the general population.

The next block of sessions examined the theoretical basis and practical construction of heat health warning systems. Warning systems are used in many application domains from public health (e.g., infectious disease surveillance) to manufacturing (e.g., fabrication defects) and it is important to consider what others have done, as many methodological issues are similar across domains. Conceptual clarity about the event of interest (what is the system intended to detect?) and its determinants are important from the outset of system development, but this conceptual foundation is often overlooked with consequences that propagate, complicating interpretation of system output and system evaluation.

Practically, one must take into account what concepts are measured (availability, cost, timeliness, and quality of data, relationship of data to concepts of interest, etc.). One must work with the realities of the informatics of automated data feeds (varying modes of data acquisition, missing data, and errors) as well as the nature of data analysis and the development of a statistical model. When making decisions under uncertainty, normative approaches to optimizing decision making can be used if one can quantify the allocation of resources against the effectiveness of intervention(s) and the probability of the event occurring.

Evaluation should consider more than prediction; system and information quality, user experiences and system benefits should be considered. When events are rare, simulated events are useful for evaluation.

The workshop participants considered the issue of objectives for a HHWS. The French system is designed to prevent specific levels of excess mortality by identifying when and where a heat wave is likely to happen and to detect the public health impacts early through monitoring of real time mortality and morbidity data. The German system uses physiologically-based indicator designed to capture thermal discomfort, which, by extrapolation, is used also to prevent mortality. Flexibility to allow for variations of local situations was seen as an important objective of the system developed by the Italian health service. This might include having different threshold levels for different cities. A long lead time to permit recalling health staff during the summer holiday season was also prioritized. One of the objectives for the designers of the synoptic system is to facilitate data transfer between the providers, analysts, and ultimate users. Another objective is to convey to the public on which days the risk to health of heat is most significant.

Several participants representing civil protection authorities discussed what decisions are made on the basis of HHWS predictions, and how and when are they made. Also discussed were needs for decision-making under uncertainty and the possible difference in information needs for health departments, civil protection authorities and the public. Some stressed the value of incorporating the effect of the urban heat island by specifying variable HHWS thresholds within cities to take the within-city distribution of temperature into account. Intervention responses to extreme heat must be based on understanding local constraints and opportunities, developing a plan, and clearly defining roles and responsibilities with critical service providers. HHWS requirements were compared between larger and smaller Canadian cities and there was also discussion on whether regions adjoining large cities need a dedicated system of their own. The potential of incorporating health surveillance data collected on a real-time basis into their HHWS was presented by participants from Italy and the U.K.

The taxonomy of different HHWSs was described as based on physiology (German Weather Service), derived from the epidemiology of heat overload (ICARO—Portugal), Bayesian approaches to prediction (France), and synoptic categorisation (Italy, U.S.). The German system is based on a physiological indicator, the perceived temperature, which is the basis for generating a heat load category. In the ICARO system, a simplified statistical model based on historical analysis of heat waves in Lisbon is used to calculate the expected heat-related mortality: a heat alert is issued when the accumulated thermal overcharge portends likely mortality impacts. Both the German and Portuguese systems use a dynamic threshold and factor short term adaptation into their models, with Germany also adjusting for moderate term adaptation. The French and Montreal systems were designed to anticipate heat waves that may result in a large excess of mortality. In France, an optimal compromise between sensitivity and specificity to avoid excess levels of mortality above 50% for large and 100% for small cities was modelled using various meteorological parameters, and optimal maximum and minimum daily temperatures were selected. The synoptic system, in use in Toronto, several U.S. cities, Italy, and Shanghai, categorizes weather data into one or several different weather types, or air masses, designated “spatial synoptic classifications”. The health response to these air masses is then assessed and “oppressive” air masses identified. Heat alerts are then based on the probability that adverse health events will occur at forecast temperature maxima within these oppressive air masses.

The differing approaches to applying HHWS-based warnings were highlighted by contrasting Philadelphia’s experience using existing structures and services recruited by the city’s Heat Task Force to serve the seasonal needs of the city versus the requirement in other cities for a dedicated coordination team which takes charge of extensive pre-season preparations. Regardless of the lead-time requirements, a critical aspect is the need for speedy delivery of information that is easy to understand and use. The television media can assist in changing the behaviour of the population, although communicating heat risk in a hot climate poses special challenges, especially when heat alerts are linked to air mass types, rather than to absolute temperatures.

The following evaluation criteria for choosing a HHWS were proposed: 1) the use of models that are based on weather data provided locally; 2) that actions can be taken rapidly; 3) it is simple to use and understand; 4) the uncertainties of both the validity factors and precision factors are explicit to the user; 5) it is compatible with the kinds of advice given; 6) it is flexible; and, 7) has high predictive accuracy. It was pointed out that some type of feedback loop is necessary to gauge the effectiveness of either predictive ability or results. Other criteria suggested were cost effectiveness, public acceptance, and integration of a partnership with different stakeholders.

The fourth theme involved a discussion of future directions for investigation. As to whether a HHWS can incorporate both death and discomfort as outcomes to be avoided, some felt that many of the causal pathways leading to mortality might be common to those for discomfort (and morbidity) which would allow the system administrators to use the same forecast data to give advice to both high-risk and lower-risk populations. The idea of developing HHWS functions on the basis of archived weather forecasts as opposed to recorded historical weather data was considered worth exploring but it was recognized that over the years forecast quality has improved and that inconsistency in the forecast models would jeopardize the feasibility of such an endeavour. Probabilistic approaches to heat health forecasting were discussed as a future direction, using statistical methods for combining a probabilistic weather forecast, with temperature versus health functions themselves incorporating statistical imprecision, to produce a joint probabilistic mortality prediction. It was felt that some decision makers would prefer a probabilistic estimate of death, rather than a deterministic estimate which does not really allow the user to access uncertainties.

The decision as to when and how to revise weather/health forecast procedures was explored in both the French and Philadelphia experiences. Both HHWSs were felt to have become less specific at capturing excess mortality over time, perhaps reflecting the growing effectiveness of interventions. To accommodate this, new heat indices and minimum 2-day heat episode duration were added to the Philadelphia system and additional criteria to guide judgment were given more prominence in the French system. Both systems allow for professional judgement to guide the ultimate decision on calling warnings and initiating emergency measures.

The problem of developing HHWS for cities/regions with small populations and /or little history of heat waves was addressed. One way to overcome the analytical challenge of small data sets is to aggregate health data into as large a region as possible while assuring climatic homogeneity. Expanding on this theme, the development of HHWS for countries with less technologically developed weather services and civil protection networks will be demonstrated in pilot projects by the World Meteorological Organisation Expert Team on Climate and Health to see whether particular countries have the capacity to implement such a system or provide a response.

Integrating spatial variability of the urban heat island effect into HHWS was the subject of several studies presented at the workshop, as this could help to more specifically identify areas and populations at risk when put together with demographic maps of social vulnerability. The most effective warnings and interventions need to target high risk populations AND high risk places, especially where the two overlap.

Integrating air quality into a HHWS presents a challenge. For heat there appears to be a threshold level above which health effects are seen, whereas for pollution, there does not appear to be such a threshold. This makes risk management for air pollution difficult because benefits can be achieved from reducing exposure across its entire range.

Integrating ongoing health surveillance (for example: current real-time daily deaths, or ambulance calls) into a HHWS has been a continuing effort in both the Italian and U.K. systems. An autoregressive model for the prediction of daily mortality in several Italian cities shows that predicted mortality was captured well in the early part of the summer, but the system performed less well later on in the season. Models based on hospital admissions were of little predictive value in the U.K., but long term time-series data are as yet unavailable.

The Italian experience of modifying warning/action thresholds based on weather and mortality experience during the season to date was deemed appropriate after the severe heat wave of 2003, when it was determined that the previously existing models based on weather alone would not have been able to predict the heat-related impact that was observed that year. The models were redefined and the time series analysis was extended to include 2003 data.

As a wrap-up, participants were invited to share what they had learned over the two days and what should be done next. It is important for decision makers to consider the hazard of extreme heat on the same level as other natural disasters because of its impact on public health. Many expressed the opinion that a warning system should be developed in parallel with an education program aimed at the public. The scientific basis for our advice should be pursued more rigorously and, in particular, efforts should be made to confirm the generalisability of testing done in the physiology lab to elderly and vulnerable populations. Some suggested that now is the time to harmonise health protection messaging for all cities. Interventions should continue to be examined at a future workshop, because practices need to be compared and assessed, and best practices recommended. Future goals agreed on by the participants include a formal review of the collective experience of HHWS so far, conducting panel studies, and trying to verify whether there is good agreement epidemiologically between symptom occurrence and mortality where both are considered as a function of heat.

RÉSUMÉ

Les 5 et 6 octobre 2006, un colloque sur les systèmes de veille et d’avertissement pour la chaleur accablante (SVACC) a été tenu à Montréal.

L’événement a réuni trente-cinq participants en provenance de six pays d’Europe et d’Amérique du Nord, œuvrant dans le domaine de la santé, de la protection civile et des services météorologiques et représentant des instances nationales, sous-nationales et municipales. Il a été organisé par la Direction de santé publique de l’Agence de la santé et des services sociaux de Montréal (DSP).

Le colloque a été subventionné par Santé Canada, le Ministère de la Santé et des Services sociaux, Environnement Canada, le Réseau de recherche en santé des populations du Québec du Fonds de la recherche en santé du Québec et l’Agence de santé publique du Canada.

Malgré le fait que les épisodes de chaleur accablante provoquent, chaque année, un niveau élevé de mortalité précoce, jusqu’à récemment, ils ont rarement fait la manchette dans la presse internationale. La situation a changé depuis la canicule européenne d’août 2003, qui a causé la mort de dizaines de milliers de personnes. L’ampleur de cette catastrophe a provoqué une réaction de la part des instances gouvernementales dans de nombreux pays, tant en Europe qu’ailleurs. Cette vague de chaleur a été entraînée par une combinaison de divers facteurs, à savoir, l'urbanisation massive, le vieillissement de la population et le réchauffement planétaire, ce qui a rendu évident le fait que seule une approche multisectorielle peut être efficace pour protéger la population contre de tels événements. Plusieurs autorités ont fait appel aux efforts collaboratifs de climatologues, de météorologues et de responsables de la santé publique pour préparer des plans de gestion de canicule tout aussi élaborés que les plans déjà mis en place pour les autres phénomènes météorologiques extrêmes. À cette fin, de nombreux pays, régions et municipalités ont instauré des systèmes de veille météorologique qui déclenchent des interventions coordonnées.

Le colloque ici mis en résumé, visait à réunir des scientifiques, gestionnaires de protection civile et de santé publique, ainsi que des responsables impliqués dans le développement de ces Systèmes d’alerte canicule et santé, afin de les amener à examiner et à évaluer les critères utilisés pour établir les seuils des différents indices correspondant aux différentes mesures d’intervention. Les participants ont partagé leurs expériences quant à l’implantation et à l’amélioration de leur SVACC et ils ont identifié les principales forces et faiblesses de ceux-ci. L’un des points le plus fréquemment abordé a été le besoin d’une collaboration multidisciplinaire et multisectorielle dans le processus d’avertissement. En effet, bien qu’établi sur des bases scientifiques, le système doit être

adapté aux besoins, aux ressources et à l’environnement spécifiques des populations ciblées.

Quatre thèmes majeurs ont été traités lors du colloque :

- La météorologie
- Les effets de la chaleur sur la santé
- Les systèmes de veille et d’avertissement pour la chaleur accablante
- Les directions futures.

Le premier volet, celui consacré à la météorologie, visait à informer les concepteurs et les utilisateurs des SVACC sur la nature et la précision des données fournies par les services météorologiques. On a aussi présenté les innovations dans le domaine des prévisions météorologiques susceptibles d’améliorer la performance des systèmes d'alerte. Une meilleure compréhension des phénomènes météorologiques et leur prévision permettront aux concepteurs et aux utilisateurs de préciser aux services météorologiques leurs besoins quant au type et au degré de précision des données météorologiques, à l’échéance de livraison et au format de présentation.

Des experts en climatologie ont décrit le rôle joué par les services météorologiques nationaux dans la conception et dans l'évaluation des SVACC de leurs pays respectifs. Le système français, établi à partir de données épidémiologiques associées aux températures extrêmes, s’appuie sur une étroite collaboration entre les services météorologiques et sanitaires. À Philadelphie, l’E.P.A. a subventionné, le premier SVACC américain, qui utilise un modèle synoptique, et a également développé des directives pour l’évaluation de système. À présent, il axe ses efforts sur la sensibilisation, sur l’éducation et sur l’intervention. Il a récemment publié un guide sur les épisodes de chaleur accablante et il participe également à l’étude des mesures visant à réduire la présence des îlots de chaleur urbains. Lors de l’élaboration du SVACC allemand, le service météorologique avait le rôle de développer le système sur la base de principes biométéorologiques et de fournir des données et des analyses météorologiques qui permettent d’orienter les interventions des administrations de santé publique des Länder (États). Au Canada, il n’existe pas de SVACC national. Le service météorologique national fournit des « produits » prévisionnels et des données météorologiques à chaque localité, selon les besoins spécifiques de celles-ci.

Un météorologue américain a présenté aux non-initiés les divers facteurs qui influencent les conditions météorologiques locales, et des représentants des services météorologiques allemand, français, américain et canadien ont expliqué les méthodes utilisées dans l’élaboration des prévisions. Il a également été question Il a également été question de l'exactitude et des limites des prévisions, ainsi que de la gamme de précision des divers paramètres météorologiques. À ce sujet, la plupart des participants s'accordaient à reconnaître qu’il était difficile de prédire avec exactitude le point de rosée. Or, dans de nombreux SVACC, cette donnée est primordiale pour le déclenchement des alertes. Depuis les trois ou quatre dernières décennies, les améliorations dans le domaine des prévisions météorologiques ont donné lieu à un gain de précision d’environ un jour par décennie, quoique les techniques de prévision varient légèrement d’un service à l’autre.

Malgré ces progrès, les prévisions de certains paramètres météorologiques restent moins précises lors des épisodes de chaleur accablante.

L'approche de « prévision d'ensemble » a été présentée en tant qu'une innovation pour l'élaboration future des SVACC. Des services météorologiques qui utilisent cette approche ont recours à des perturbations aléatoires des conditions initiales et à des modèles numériques divers pour générer une série de résultats pour une période de trois à quatorze jours. Au Canada, seize simulations sont exécutées, qui produisent seize solutions. (On teste présentement d'autres modèles, qui utilisent plus de simulations et des données plus détaillées.) À partir de ces solutions, Environnement Canada calcule la « probabilité » de chacun des paramètres météorologiques. (On calcule cette probabilité en divisant le nombre des simulations qui prédisent le paramètre météorologique par seize.) Des gestionnaires des organismes de protection civile ont demandé des prévisions météorologiques à une échéance de plus de cinq ou dix jours, pour mieux prévoir les phénomènes météorologiques extrêmes et pour assurer la mise en place des systèmes de mesures d'urgence. L'importance de la prévision saisonnière a déjà été démontrée. Par exemple, le 1 mai 2003, le Centre européen de prévision météorologique à moyen terme a émis une prévision probabilistique pour la période juin-août, selon laquelle il y avait une forte probabilité que les températures en Europe du Sud se situent dans le tiers supérieur. Cette information s'est avérée très utile, car un mois avant le début d'été, elle présageait un été très chaud, ce qui laissait déduire qu'au cours de cet été chaud, il y aurait des journées de canicule. Une telle prévision permet donc de sensibiliser la population et de préparer des mesures d'intervention. Les prévisions saisonnières incluant la probabilité des phénomènes météorologiques extrêmes seraient utiles non seulement pour le domaine de la santé, mais aussi pour d'autres domaines, notamment pour celui de l'agriculture et des transports.

Le deuxième sujet concernait les effets de la chaleur sur la santé. Plus précisément, il s'agissait des méthodes pour évaluer la corrélation entre chaleur et état de santé et les implications de celles-ci pour la définition des seuils. En guise de préambule, il a été rappelé aux participants que n'importe quelle relation établie entre chaleur et état de santé doit prendre en considération la population cible, les résultats cliniques enregistrés et les paramètres météorologiques (température et autres) observés. D'autres facteurs pourraient également être envisagés, notamment la possibilité d'effets cumulatifs (une fonction de la durée des épisodes de chaleur accablante), d'effets prolongés, d'effets retardés, les effets selon la période de l'été où l'exposition a lieu, ainsi que les effets conjoints de l'exposition à la température élevée et à la pollution atmosphérique.

De nombreuses résultats cliniques ont été ou pourraient être étudiées en fonction de l'exposition à la chaleur. Il s'agit notamment des décès physiologiquement liés à la chaleur, de tous les décès d'origine non traumatique, du nombre de décès dépassant les niveaux prévus selon les tendances à long terme, et de plusieurs indicateurs de santé tels que les consultations à l'urgence, les appels aux services ambulanciers, les appels aux lignes d'information sur la santé et le taux d'hospitalisation. La population cible peut inclure certaines populations vulnérables (notamment les personnes âgées, les malades et les jeunes enfants), les travailleurs, les athlètes ou tout le monde. Parmi les cadres de temps envisagés figuraient la journée même où l'épisode de chaleur accablante s'est produit, un court laps de temps entre l'exposition et la manifestation du problème de santé nécessitant une intervention (zéro à deux jours), ainsi que des délais de suivi court (huit jours ou moins), moyen (des mois) ou long. Plusieurs procédures peuvent être utilisées pour évaluer l'impact de l'épisode de chaleur accablante, notamment l'analyse de l'épisode ou une analyse de la réponse sanitaire en fonction de la température (telles les séries chronologiques). L'analyse peut concerner uniquement les mois d'été, la période estivale et une intersaison, ou bien des données enregistrées tout au long de l'année. L'analyse des épisodes de chaleur accablante dépend de la façon de définir ceux-ci. Or, il n'existe pas de consensus général à ce propos. On a étudié la relation entre les résultats cliniques et une gamme de facteurs, tels les principales caractéristiques météorologiques (la température, l'humidité, etc.), certains indices météorologiques (comme la température apparente) et les conditions générales. Des facteurs reliés à l'exposition à la chaleur (comme la qualité de l'air) ont également été pris en considération.

Selon toute évidence, les décès dus aux coups de chaleur ne contribuent que dans une faible proportion au taux de mortalité relié aux épisodes de chaleur accablante, tandis que les décès cardio-vasculaires en constituent souvent la cause majeur. La période d'induction entre l'exposition à la chaleur accablante et le décès est relativement courte, et les données empiriques provenant de plusieurs villes nord-américaines montrent que le niveau de mortalité non traumatique atteint un pic deux jours après le début de la période de canicule. Selon certaines observations, la température nocturne élevée constitue un facteur important dans la mortalité liée à la chaleur accablante, en particulier dans les zones urbaines densément peuplées. Lorsque la température se situe au-dessous ou au-dessus du niveau optimal, on observe un niveau de mortalité quotidienne accru pratiquement chez toutes les populations urbaines. Ce niveau optimal de température varie d'une ville à l'autre. Il est plus élevé lorsque la température moyenne est plus chaude, que ce soit pour des raisons géographiques (sud/nord) ou chronologiques (le réchauffement progressif de la planète). Toutefois, l'incidence de la chaleur et du froid sur la mortalité s'est atténuée quelque peu au cours des six dernières décennies, probablement grâce à l'amélioration de l'état de la santé de la population ou à une meilleure isolation des immeubles. Les tentatives de déterminer la corrélation entre la température et la mortalité quotidiennes tout en prenant en considération la qualité de l'air, l'humidité et le type de masse d'air, n'ont pas donné des résultats satisfaisants. Cela est probablement dû aux différences parmi les villes, ou bien aux différences méthodologiques dans la paramétrisation des facteurs traités.

Les épisodes plus longs ainsi que les épisodes ayant lieu plus tôt durant l'été ont été associées à un taux de mortalité plus élevé. Le fait que les épisodes de chaleur accablante qui surviennent plus tard en été provoquent moins de décès (si l'on tient compte de la température), semble indiquer que l'acclimatation à la chaleur pourrait prévenir le décès. Le risque de décès lié à la canicule touche surtout les personnes âgées, mais les maladies chroniques, en particulier les maladies cardio-vasculaires ou psychiatriques, constituent également un important facteur de risque. En ce qui concerne les jeunes enfants, des études physiologiques ont révélé que les enfants en bas de cinq ans peuvent être incapables de s'adapter à la chaleur en augmentant leur débit cardiaque. Pour les enfants appartenant à ce groupe d'âge, le fait d'être laissé seul dans une voiture fermée constitue un facteur de risque de mortalité. Les recherches indiquent que les îlots de chaleur urbains peuvent amplifier la magnitude des températures extrêmement élevées. Cependant, dans les régions rurales, on peut observer un taux similaire de surmortalité à la suite des épisodes de chaleur accablante. Par contre, il semble exister certaines différences entre l'Europe et l'Amérique du Nord en matière de mortalité reliée à la chaleur. En effet, en Amérique du Nord, ce sont les hommes âgés qui constituent le groupe le plus vulnérable, tandis qu'en Europe, les femmes sont plus à risque.

De plus, comparé à l'Europe, aux États-Unis, un pourcentage plus élevé de décès reliés à la canicule sont attribués à l'hyperthermie. Une autre différence concerne le recours à l'hospitalisation pour des motifs attribuables à une vague de chaleur. Ce phénomène existe aux États-Unis, mais, pour une raison encore inconnue, il ne semble pas être observé en Europe. Enfin, on a souligné le fait qu'aux États-Unis, un plus grand pourcentage de la population possède un climatiseur.

Il a également été question des effets pathophysiologiques de la chaleur ambiante, et de la façon dont ses effets varient en fonction de l'humidité, de l'exposition au soleil et du vent. La plupart des études sur l'adaptation à la chaleur à court terme (en quelques jours), à moyen terme (au cours d'une saison) et à long terme ont été effectuées sur des sujets en santé et dans les conditions de laboratoire. On ne sait pas encore à quel point les résultats de ces recherches peuvent être extrapolés aux populations vulnérables. Il a été démontré que certains comportements individuels (les activités, l'hydratation, la façon de s'habiller) peuvent influencer la tolérance à la chaleur, mais la possibilité à recourir à des comportements adaptatifs peut être limitée pour certains groupes, notamment pour les personnes confinées au logis ou exposées à l'air climatisé. À cause de ces limitations, il existe une population potentiellement très vulnérable, qui peut avoir besoin d'être protégée même d'un niveau modéré de stress dû à la chaleur, et non seulement d'un niveau élevé qui cause les coups de chaleur et l'épuisement dû à la chaleur au sein de la population générale.

Le bloc de séances suivant a été consacré à l'étude des fondements théoriques et de la conception pratique des SVACC. On utilise des systèmes d'avertissement dans les domaines aussi variés que la santé publique (par exemple, pour la surveillance des maladies infectieuses) et la fabrication (par exemple, pour les défauts de fabrication). Il importe de prendre connaissance de ces différents systèmes, car les enjeux méthodologiques sont similaires dans tous les domaines. Avant d'élaborer un système d'avertissement, il est nécessaire de clarifier quel épisode doit constituer l'objet de la surveillance (ce que le système est censé détecter) et quels sont les déterminants de celui-ci. Cependant, on néglige trop souvent de régler ces questions conceptuelles à l'étape préliminaire, ce qui a des répercussions négatives plus tard sur l'interprétation des résultats et sur l'évaluation du système.

En termes pratiques, on doit prendre en considération quels éléments sont mesurés (disponibilité, coût, rapidité des résultats, la qualité des données, la pertinence des données pour les concepts à surveiller, etc.) De plus, on doit composer avec les réalités de la transmission automatique des données (différents modes d'acquisition de données, des données manquantes, des erreurs), sans oublier la nature de l'analyse des données et la conception d‘un modèle statistique. Lorsqu’on doit prendre des décisions malgré l’incertitude, on peut avoir recours à des approches normatives pour optimiser la prise de décisions, à condition que l’on soit capable de quantifier l’allocation des ressources, l’efficacité de l’intervention et la probabilité que l’épisode se produise.

Au-delà des prévisions, l’évaluation devrait aussi prendre en considération la qualité du système et des données, ainsi que les avantages liés à l’utilisation du système. Lorsque les épisodes sont rares, on peut utiliser des épisodes simulés pour l’évaluation.

Les participants ont aussi considéré l’enjeu des objectifs d’un SVACC. Le système français est conçu pour prévenir des niveaux spécifiques de mortalité excessive, en identifiant le moment et l’endroit où une vague de chaleur est susceptible de se produire, et pour détecter rapidement les répercussions sur la santé publique, grâce à la surveillance continue et le traitement en temps réel des statistiques de mortalité et de morbidité. Le système allemand utilise un indicateur basé sur des données physiologiques, afin de révéler l’inconfort thermique, ce qui, par extrapolation, peut être aussi utilisé pour prévenir la mortalité. En ce qui concerne le système élaboré par le service national de santé italien, une de ses visées était la flexibilité pour pouvoir concevoir les variations entre diverses situations locales. Pour ce faire, il peut être nécessaire de déterminer des niveaux de seuil différents selon les villes. Une autre priorité était d’obtenir les prévisions suffisamment tôt pour pouvoir rappeler les professionnels de la santé durant les vacances d’été. Un des objectifs des concepteurs du système synoptique a été de faciliter le transfert des données entre les fournisseurs, les analystes et les utilisateurs finaux. Un autre objectif était de pouvoir indiquer au public les journées où le niveau des risques dus à la chaleur est le plus élevé.

Plusieurs participants représentant les autorités de protection civile ont discuté de la nature des décisions prises sur la base des prévisions des SVACC, ainsi que de la façon et du moment des prises de décision. On a aussi traité des éléments nécessaires pour prendre des décisions dans des conditions d’incertitude, ainsi que des différences possibles entre les besoins des départements de santé publique, des autorités de protection civile et du public général en matière d’information. Quelques participants ont souligné la pertinence de prendre en considération l’effet des îlots de chaleur urbains en déterminant de différents seuils à l'intérieur des villes, ce qui permettrait d’envisager la distribution de la chaleur à l'intérieur de la ville. Pour déterminer les mesures d’intervention à adopter en cas de chaleur accablante, on doit d’abord comprendre les possibilités et les limitations locales, on doit élaborer un plan, et on doit s’entendre avec les fournisseurs de services critiques pour clairement identifier les rôles et les responsabilités de chacun. On a comparé les attentes des grandes et des petites villes canadiennes envers les SVACC. On a envisagé s’il était nécessaire d'élaborer des systèmes spécifiques pour les régions adjacentes aux grandes villes. Des participants en provenance d’Italie et du Royaume-Uni ont parlé des avantages d'incorporer dans les SVACC des données de surveillance médicale relevées en temps réel.

On a classé les différents SVACC en quatre catégories : ceux basés sur la physiologie (service météorologique allemand), ceux dérivés de l’épidémiologie de l’exposition à une chaleur excessive (ICARO – Portugal), ceux utilisant les approches bayésiennes (la

France) et ceux ayant recours à la catégorisation synoptique (Italie et États-Unis). Le système allemand est fondé sur l'indicateur physiologique de température perçue, qui est à la base de la génération des catégories de surcharge thermique. Le système ICARO utilise un modèle statistique simplifié, basé sur l'analyse historique des vagues de chaleur à Lisbonne, pour calculer le niveau prévu de mortalité liée à la chaleur. Un avertissement de chaleur est émis lorsque la surcharge thermique accumulée présage un effet très probable sur la mortalité. Les systèmes allemand et portugais utilisent tous deux un seuil dynamique et incluent l'adaptation à court terme dans leurs modèles. L'Allemagne utilise aussi un modèle conceptuel pour l'adaptation à moyen terme Les systèmes français et montréalais ont été conçus pour anticiper les canicules pouvant mener à une surmortalité significative. En France, on a modelé un compromis optimal entre la sensibilité et la spécificité, dans le but d'éviter que la surmortalité dépasse 50% dans les grandes villes et 100% dans les petites. Pour ce faire, on a utilisé des paramètres météorologiques variés, et on a établi l'optimum pour les températures quotidiennes maximum et minimum. Le système synoptique est utilisé à Toronto, dans plusieurs villes américaines, en Italie et à Shanghai. Ce système utilise la classification synoptique spatiale des données météorologiques, c'est-à-dire, il classe les conditions météorologiques ou les masses d'air dans un ou plusieurs types. Par la suite, le système évalue l'effet de ces masses d'air sur la santé et il identifie les masses d'air « accablantes ». Les alertes à la chaleur sont alors basées sur la probabilité d'effets néfastes pour la santé qui peuvent apparaître aux températures maximales prévues durant la présence de ces masses d'air accablantes.

Pour mieux mettre à jour les différentes approches utilisées pour ces systèmes, on a comparé le cas de Philadelphie, qui a recours à des structures et services déjà en place, mis au service des besoins saisonniers par le groupe d'intervention de la ville, et celui des autres villes qui nécessitent un groupe de coordination spécialisé, chargé des préparations pré-saisonnières intensives. Même si l'on fait abstraction des besoins liés au délai de réponse, l'accès rapide à des informations faciles à comprendre et à utiliser demeure un autre aspect primordial. Le réseau télévisé peut jouer un rôle pour inciter la population à modifier ses comportements, quoique la tâche de communiquer les risques liés à la chaleur dans un climat chaud pose des défis particuliers, surtout lorsque les avertissements de chaleur sont liés aux types de masse d'air plutôt qu'aux températures absolues.

Pour le choix d'un SVACC, les critères d'évaluation suivants ont été proposés : 1) utiliser des modèles basés sur des données météorologiques prélevées localement ; 2) permettre des actions rapides; 3) être simple à comprendre et à utiliser ; 4) indiquer aux utilisateurs de façon explicite l'incertitude des facteurs de validité et de précision ; 5) être compatible avec le type de conseils donnés ; 6) être flexible et 7) avoir un pouvoir de prédiction élevé. On a souligné la nécessité d'une certaine rétroaction afin d'évaluer l'efficacité de la capacité de prédiction ou des résultats. Parmi les autres critères, on a suggéré la rentabilité, l'acceptation du public et le partenariat entre les différents intervenants.

Lors de la quatrième section, on a discuté des futures orientations pour la recherche. On a discuté la possibilité de vérifier si un SVACC pouvait inclure la mortalité et l'inconfort comme des facteurs à éviter. Quelques participants étaient d'avis que plusieurs des liens causaux entre chaleur accablante et mortalité pouvaient exister également entre chaleur et inconfort (et morbidité), ce qui pourrait permettre aux gestionnaires du système d'utiliser les mêmes données prévues pour conseiller tant les populations à risque élevé que celles à faible risque. Certains trouvaient que l'idée de développer des SVACC basés sur les prévisions météorologiques archivées, plutôt que sur des données historiques, valait la peine d'être explorée, mais reconnaissaient qu'avec les années, la qualité des prévisions météorologiques s'était améliorée et qu'une divergence dans les modèles de prévision pourrait entraver la réalisation d'une telle entreprise. On a discuté des approches probabilistes pour les prévisions de l'impact de la chaleur sur la santé comme future orientation. Ces approches permettent de créer une prédiction probabiliste conjointe de mortalité, grâce à des méthodes statistiques qui combinent une prévision météorologique probabiliste avec les corrélations entre la chaleur et la santé (corrélations établies en prenant en considération l'imprécision statistique). Il semble que certains administrateurs préfèrent l'estimation probabiliste des décès à l'estimation déterministe, cette dernière ne permettant pas réellement à l'utilisateur d'évaluer le facteur d'incertitude.

La décision concernant le moment et la façon de réviser les procédures de prévisions météorologiques/sanitaires a été explorée dans le cas des systèmes français et philadelphien. Il semble qu'au fil du temps, les deux systèmes sont devenus moins spécifiques pour signaler la surmortalité, ce qui peut être attribué à l'amélioration de l'efficacité des interventions. Afin de prendre en considération ce phénomène, de nouveaux indices de chaleur et une durée minimum de deux jours ont été ajoutés au système de Philadelphie, tandis que, dans le système français, on a donné plus d'importance à des critères additionnels dans les prises de décision. Les deux systèmes laissent une place au jugement des professionnels dans la décision finale concernant l'émission des avertissements et le déclenchement des mesures d'urgence.

Il a aussi été question des difficultés à concevoir des SVACC pour des villes ou régions ayant une petite population et/ou qui n'ont connu que peu d'épisodes de chaleur accablante. Une façon de surmonter le défi analytique posé par les petits ensembles de données est de regrouper les données sanitaires pour une région aussi large que possible tout en s'assurant de l'homogénéité climatique. Dans le même ordre d'idées, le WMO Expert Team on Climate and Health mènera des projets pilots sur l'élaboration des systèmes d'avertissement pour des pays dont les services météorologiques et les réseaux de protection civile sont technologiquement moins développés, pour déterminer si tel ou tel pays a la capacité d'implanter un SVACC ou des mesures d'intervention.

L'intégration de la variabilité spatiale de l'effet des îlots de chaleur urbains dans un SVACC était le sujet de plusieurs études présentées à ce colloque, étant donné que cette approche, utilisée conjointement avec des cartes de vulnérabilité sociale, pourrait permettre d'identifier les zones et les populations à risque. Les avertissements et les interventions les plus efficaces sont ceux qui ciblent tout aussi bien les populations à risque élevé que les zones à risque élevé, en particulier lorsque ces deux entités coïncident.

L'intégration de la qualité de l'air dans un présente un défi. En effet, dans le cas de la chaleur, il semble exister un niveau-seuil, au-delà duquel les effets sanitaires se manifestent, tandis qu'on ne peut pas observer un tel seuil pour la pollution. Cela complique la gestion des risques pour la pollution atmosphérique, car, à tous les niveaux, les bénéfices sont observés lorsqu'on réduit l'exposition.

Un modèle autorégressif pour la prévision de la mortalité quotidienne dans plusieurs villes italiennes montre que la mortalité a été bien prédite pour le début d'été, mais plus tard dans la saison le système s'est montré moins performant. Au Royaume-Uni, les modèles basés sur l'hospitalisation avaient peu de valeur prédictive, mais les données des séries chronologiques à long terme restent encore inaccessibles.

À la suite de la canicule de 2003, l'Italie a jugé nécessaire de modifier son seuil d'avertissement et de déclenchement de mesures d'intervention en se basant sur les conditions météorologiques et la mortalité durant la saison en cours. En effet, on avait déterminé que les modèles précédents n'auraient pas permis de prédire l'impact relié à la chaleur observée cet année-là. Les modèles ont donc été redéfinis et la portée de l'analyse de la série chronologique élargie afin d'inclure les données de 2003.

En tant qu'activité de clôture, les participants ont discuté de ce qu'ils avaient appris au cours de ces deux journées et ils ont proposé des actions à entreprendre. Étant donné les effets de la chaleur accablante sur la santé de la population, il importe que les responsables attribuent à ce risque autant d'importance qu'aux risques liés aux autres catastrophes naturelles. Plusieurs ont mentionné que la mise en place systèmes d'avertissement devraient s'accompagner de l'élaboration d'un programme d'éducation destiné au public général. Les fondements scientifiques de nos avis devraient être poursuivis plus rigoureusement, de même que les efforts pour confirmer la généralisation aux personnes âgées et aux populations vulnérables des connaissances provenant des études conduites en laboratoire. Selon certains, le moment est venu pour harmoniser la diffusion des messages de protection pour toutes les villes. Il faudrait continuer à évaluer les interventions lors des colloques à venir, car on a besoin de comparer et d'évaluer les pratiques et d'identifier les pratiques à recommander. Selon les participants, les prochains objectifs devraient inclure une révision formelle des expériences collectives accumulées en matière des, des études de panel, ainsi qu'une étude de la corrélation épidémiologique entre la présence des symptômes et la mortalité, lorsque ces deux paramètres sont considérés comme étant reliés à la chaleur.

SECTION 1

METEOROLOGY AS APPLIED TO HHWS

1. Role of the national weather services in HHWS: Brief Overview - *Françoise Bénichou, Jason Samenow, Christina Koppe, Denis Bourque*

Françoise Bénichou – Météo-France. (Powerpoint)

Françoise Bénichou presented a brief overview of the role of the national weather service in the French heat health warning system. Météo-France has worked with INVS (French National Institute of Health Surveillance) to generate an HHWS designed to produce alerts of potential tragedies such as that of 2003. It and INVS have been partners in the conception of the system.

Here is how it works. During the period from June 1 to August 31, Météo-France produces daily weather data to support the implementation of heat health protection measures. It contributes to the decision of declaring alerts and delivers the warnings. Also, it keeps records of weather data and of warnings given, and, along with the Health Service, contributes to the post-season evaluation of the performance of the summer's HHWS.

There are two components to Météo-France's heat-related activities: 1) a national heat wave plan operated by the Health Service capable of implementing measures according to the seriousness of the event, and 2) the heat wave warning as part of the overall Météo-France meteorological warning system.

After the dramatic events of 2003 these two parts were approved for development and implementation by the French Ministry of Health. Prior to this, Météo-France did not have heat wave warnings as part of its meteorological warning system. Météo-France added a new parameter, a bio-meteorological index (IBMn, IBMx) that is calculated daily and is equal to the average of the extreme temperatures forecast for the next three days: the 3-day minimum temperature average, IBMn(D1) = {Tn(D1)+ Tn(D2) + Tn(D3)}/3 and the 3-day maximum temperature average, IBMx(D1) = {Tx(D1)+ Tx(D2) + Tx(D3)}/3. A health risk is identified for each day of the set of three days when the indices (IBMn *and* IBMx) go above the preset thresholds. An alert is contemplated as soon as a positive deviation in indicated in the IBMn and IBMx indices, i.e. values ≥ threshold levels. A projection of up to 7 days into the future is provided. Importantly, there is close collaboration between INVS and Météo-France. These projections are provided daily to the National Institute of Health Surveillance (INVS) on a dedicated website at 1:30 pm through automated means. At 2:00 pm, Météo-France regional centres contact the central forecast office to assess the likelihood of meeting/exceeding threshold levels, check for consistency, etc. At 3:30 pm, if the situation calls for it, a crisis conference call is held between Météo-France and INVS to develop a heat wave recommendation for each affected region and then Météo-France finalizes and provides the information in bulletins and in map form showing these IBMn and IBMx indices for day -1 to day +5 highlighting those locations where a positive deviation from the threshold is indicated for both indices. It also provides a chart showing the deviation from normal in the average temperature for the past two months including a projection for the next 7 days. Health Services then activate the national heat wave plan as required.

Prior to 2004, Météo-France did not have INVS as a partner. The procedure has proved relevant and efficient since 2004, especially during the major events of the summer of 2006. Other more complicated methods of assessing the prediction of excess mortality through meteorological data have been successfully tested (e.g. a very good correlation was found with the integral of temperatures above 37°C, => a heat load measure) but from a user's point of view, the main purpose is to anticipate and detect a heat wave event and to have a strong organization in place to warn and protect the population.

Question of clarification from the floor: is the warning purely based on maximum and minimum temperature? No, temperature is the main parameter; it shows up in the automated calculation as an average over three days but also taken into account are relative humidity, and other non-meteorological considerations from the community in making the final decision on issuing an alert.

Jason Samenow – US EPA Office of Atmospheric Programs. (Powerpoint)

Jason Samenow, from EPA addressed the issue of his agency's role in HHWS especially from the urban community perspective as being more in the area of capacity building, intervention and response. Deaths from heat in the USA exceed those from hurricanes, lightening, tornadoes, floods and earthquakes combined and are estimated at around 1500-1600 per year (Kalkstein & Davis). In 1995 alone, over 700 people died in Chicago as a result of a single heat episode. There are particular population groups which are more at risk such as older adults, the poor, individuals living alone, the very young, and those with mental illness or chronic disease. Also at risk are those living within the urban heat island of cities with a highly variable climate.

EPA's involvement in the area of heat and health relates to its interest in helping to develop adaptation strategies for responding to the effects of global climate change. The International Panel on Climate Change (IPCC) projects an increase in the frequency, duration and intensity of such events. Additional rationales include:

- Lack of public recognition of the danger of excessive heat given that, as opposed to other extreme weather conditions, it is not accompanied by infrastructure damage
- The fact that many heat-related deaths are not reported.
- Increasing urbanization which will enhance the urban heat island effect.
- An aging population which will increase numbers of the most vulnerable demographic.

It is felt that heat-related deaths are largely preventable through direct response and mitigation. EPA funded the first heat health warning system for Philadelphia and Washington DC in the early 1990s working with Larry Kalkstein (University of Delaware). Lately, EPA has been focused more on outreach, education and intervention while the weather service has taken over the operational role of HHWS. Recently EPA has worked with The Weather Channel to create programming on excessive heat events, covering risk factors, what people can do to protect themselves, what communities can do, etc. EPA produced a half hour special television program with The Weather Channel featuring Dr. Robinson that aired in 2005 and 2006. Most recently, EPA produced the

Excessive Heat Events Guidebook, an inter-agency effort, addressed later (available online at: http://www.epa.gov/heatisland/about/heatguidebook.html). EPA also funded an analog study (Kalkstein, in press) on what would be the impact on the USA of a statistically anomalous heat wave of the magnitude of the European heat wave of 2003. (What would the climate characteristics be? How many heat-related deaths would occur?) (– this paper was recently submitted for publication and has not yet been accepted). EPA also does work on the urban heat island and mitigation. EPA has an urban heat island reduction initiative which works on technologically cool roofs, green roofs, shade tree planting, etc. that schools may employ (more information is available at: http://www.epa.gov/heatisland/index.html). EPA has a website which has a lot of information on actions taken across the US with respect to urban heat island reduction measures. EPA is working on an urban heat island guidebook which provides detailed information about different technologies (still under development, not published yet). EPA has a radiation Mitigation Impact Screening Tool (MIST) which is a type of calculator where one can see what the benefits are with respect to climate and air quality, after taking heat island reduction measures (see: http://www.heatislandmitigationtool.com/). EPA is involved in education and outreach. Also, EPA convenes conference calls where researchers and Federal and state and local officials discuss heat island reduction strategies.

Dr. Christina Koppe – Deutscher Wetterdienst. (Powerpoint)

The German meteorological service (DWD) belongs to the national German government while the health services responsible for intervention belongs to the individual federal states, e.g. Bavaria. In Germany, the DWD has a well defined role in HHWS. This role of the DWD is based on the law which established it: one of the tasks of the German Weather Service is the “provision of meteorological services for the general public or for single clients and users especially ... the health sector...”. That is why DWD has provided weather information for the health sector for a long time. The health role explains why DWD has a special department for Human Biometeorology. The DWD role in the German HHWS was to develop the system (to be addressed in detail on the second day of this workshop). DWD prepares a three-day forecast but uses only the coming two days and from this, heat load categories are assigned. From these category assignments, DWD decides if a warning is required or not. And warnings are issued for 14 warning regions each of which has a more or less homogeneous climate. Warnings are issued for all altitudes BUT it is specified in the text of a warning up to which height the warning is valid, i.e. heat related health effects are expected. Warnings are distributed to the general public via the Internet and by other means (email, ftp, fax, etc.) to health authorities, directly to hospitals, etc. (health and social service professionals) and also to the state ministries of health. The health care and social organizations and the health ministries within the German states are responsible for the intervention. The weather service cannot give these warnings to the radio or TV, as by federal statute, must be done by the state ministries. Radio and TV are controlled by the states.

Denis Bourque, Environment Canada, Meteorological Service of Canada (MSC), Business Policy. (Powerpoint)

Some form of heat health warning system is needed in Canada. The information that will result from this workshop is going to be very useful for the Meteorological Service of Canada (MSC) to help understand how to provide the related services. In Canada, no one heat health warning system exists for all. There are systems, which vary by location, operated by health agencies for various regions or municipalities. Any formal HHWS participation has been recent, usually within the last ten years.

As part of its normal suite of products, the MSC has been delivering a heat load product, known as the Humidex, since the late 1960s. The Humidex combines temperature and humidity, but this is not to be considered a heat health warning system (for further explanation, refer to www.msc-smc.ec.gc.ca/cd/brochures/humidity_e.cfm#2).

The HHWS systems that exist in Canada right now rely on information that the weather service provides. Since 2004, Montreal (Canada's 2nd largest city) has been using the standard meteorological forecast products; the MSC does not produce a customized product for Montreal. Montreal warnings delivered by Environment Canada are based on temperatures of 30° C or more and a Humidex level of 40 or more. When the weather forecast predicts an average maximum temperature greater or equal to 33°C and an average minimum temperatures greater than or equal to 20°C over a three day period, the Montreal Public Health Department consults with the desk forecaster according to an agreed procedure before emitting an alert to its various partners, asking them to prepare to intervene if the predicted temperatures do materialize. Therefore, a three day weather forecast is required in Montreal for alerts to be emitted (see later for a more complete description of this process).

Since 2000 in Toronto (Canada's largest city), and since 2006 in the Peel Region (immediately west of Toronto), the Kalkstein synoptic typing method is used. This method requires custom forecast products from the MSC. Specifically, the meteorological forecast data for Pearson International Airport is required, but MSC forecasters must interact with the forecast-generating system and extract specific files with temperature, dew point temperature, wind speed and direction and cloud cover forecasts for the next 48 hours at three hour intervals. The data is then sent to Kent State where they are processed, whereupon forecasts of heat-health risks are transmitted to the two municipalities. The dew point temperature module in Canada's forecast system needs manual intervention (a workload item), as it has not yet reached the level of precision where the MSC can solely supply the model outputs.

The city of Ottawa (Canada's 4th largest city) uses products from the standard MSC suite. Essentially, they look for two consecutive days where the Humidex is forecast to reach 40 or greater. As soon as this happens, they invoke their warning system.

There are other cities in the country that are contemplating or have actually adopted similar approaches, but since many of them are basing their system on using MSC's standard forecasts products, a complete identification of them is therefore not possible.

In a manner analogous to efforts a few years ago with the wind chill index, the MSC has been thinking about modifying the Humidex to convert it from an artificial estimate to a proper human biometric measurement, but this work has not yet been undertaken.

A final comment: in Canada, health jurisdictions issue heat-health warnings, while the meteorological service does not issue any of the warnings. However, they do provide dangerous weather warnings that often carry health protection advice intended for the general public.

2. An overview of weather synopses: Weather systems and weather, what influences local weather. *Anton Haffer – USA NWS Arizona State Liaison & Forecast Office* (Powerpoint)

With the background of his slides in dramatic burnt sienna, oranges and yellows, Tony Haffer provided a brief overview of the forces behind the weather. Tony explained that the engine of the weather is the sun, 150 million km away, whose short wave radiation hits the earth in 8 minutes and 20 seconds where it is absorbed by water, land and ice and from which it is radiated back upwards as long wave radiation. Thus the earth is heated from the bottom up, and the atmosphere warms and cools “locally” influenced by the long wave radiation: parts of the atmosphere rise or fall dependant upon the “thermal” relativity of the surrounding environment. The earth's rotation drags the atmosphere along with it and the “conservation of angular momentum” at times flings or speeds up northward bound parts of the atmosphere or conversely slows down parts of the atmosphere moving “equator-ward”. Depending where you are on the planet will determine how cold or hot and how dry or wet you are. Slide 6 shows the Energy-Heat-Water cycle. The earth's atmosphere is constantly trying to achieve a state of equilibrium; the sun’s radiation hitting all sorts of surfaces (land, water, forests, ice, snow, urban areas, etc.) causes differences in temperatures some of which result in storms, some of which result in fog, some of which result in clear blue skies, etc. all of which involve the switching of energy from one part of the atmosphere to another. Thus what we experience locally is in reality just part of this constant global atmospheric energy exchange. Each of the weather elements are inter-related, but in the United States temperature has the biggest impact on the nation’s economy and welfare. Demographically, humans are on the move from rural to urban areas and, within the next 30 years, the portion of urban dwellers will rise from less than half to two-thirds of the world's population, increasing the urban heat island problem. Natural disasters are mostly inter-related as are weather elements in general, for example forest fires develop in areas of dry or draught conditions. Terrain features affect the weather. In the south-western U.S., cold high pressure dominates winter cutting off moist maritime tropical air masses. The coastal mountain ranges remove east Pacific moisture from passing mid-latitude storm systems and extensive heat episodes develop early in summer under stagnant air mass regimes.

Our challenge, stemming from this workshop, is to get folks thinking in a proactive manner but traditionally nothing happens until you make headlines... while problems have occurred in many U.S. cities (Chicago, Washington, Philadelphia, even Phoenix) the public does not realize that heat is the silent killer. In the U.S., the number of deaths caused by heat is far greater that all other natural disasters that make the headlines (in Arizona 30-35 deaths per year are reported). So why is heat being overlooked? After a tornado you can visually see the impact while, by contrast, the before and after pictures of the infrastructure/residential communities, etc. of a heat event look identical. The breaking news is that NASA researchers say that the earth is the warmest it's been in 12,000 years. Researchers at The National Academy of Sciences say the planet's temperature has climbed over the last 30 years with recent global warming, bringing the earth's temperature within 1.8 degrees F of the maximum temperature of the past million years.

3. Weather forecasting: an overview, including, for tomorrow and the following day, *and* for days 3-10 ahead, what information (measurements) is collected/ available/ deliverable, the differences between predictive techniques in use, and how predictions are integrated into a weather forecast - *Panel discussion initiated by Denis Bourque (15 minutes) and including Françoise Bénichou, Anton Haffer, Christina Koppe*

Denis Bourque, Environment Canada, Meteorological Service of Canada, Business Policy (Powerpoint)

Denis identified the objective of this overview session as providing the non-meteorologist participants in this workshop with a basic generic understanding of the processes which a national meteorological service goes through in order to produce forecasts of weather parameters required for the operation of a Heat Health Warning Systems. Denis indicated that the processes could be categorised into five general steps: 1) Initial Conditions; 2) Analysis; 3) Processing; 4) Extraction; and 5) Distribution.

In the Initial Conditions step, the meteorological service observes, measures, collects and assembles all the data about the atmosphere that it can using a variety of instruments, aircraft, satellites, etc. The atmospheric data collected are basically energy information measured as Temperature (thermal energy), Humidity (atmospheric moisture), wind speed and direction, and atmospheric pressure and can include other parameters such as radiation.

To carry out the second step, the data are placed within a 3-dimensional grid of the atmosphere, of various horizontal grid resolutions and with up to 60 vertical levels, where every 'cube' in the grid contains values for each of these parameters. This information is presented in various ways including two-dimensional maps at various levels which allows us to understand what is happening at any point in time and set the stage for the next step, processing.

In the processing step, the dynamic equations for motion and thermodynamic treat the data at each 3D grid point, time-stepping forward in short increments. Because of the limitations of computing power, both the grid resolution and the length of the time step are necessarily coarser than ideal, resulting in less than perfect precision. Supplementary techniques, such as "nested grids" where the resolution of the nested grids are higher over the areas of interest, are used as a compromise. Specialty modules are also invoked to incorporate the physics of water, the exchange of radiation energy, the various surfaces and the heat and moisture exchange with them, the geography and orography, and the latent heat processes. Even with all of these techniques, we still do not have the resolution necessary to capture the details of the urban heat island, such as the heat storage and radiation of each building and surface in a city. The result of this processing step is a 3-dimensional image of the atmosphere at short time intervals (e.g. 5 minutes) for as much as 10 days in the future; the quality and accuracy vary depending on the parameter and fall with the time length of the forecast. For example, the accuracy of the dew point temperature is not nearly as good as the temperature. Nevertheless, we now have a good general picture of the weather situation.

But a HHWS does not depend on a general indication; it requires specific information about the temperature, the humidity, the cloud cover, etc. Thus special modules have been written to extract these data from the models. Using these, it is possible to develop a picture of various desired parameters at various levels; for example, a picture of relative humidity at 3 km above sea level is a good indicator of mid-level clouds. Similarly, projections of 24-hour total precipitation can be generated. And, indeed tables of point values for a distribution of parameters required for a HHWS can be produced (in Canada, this is done using the SCRIBE tool).

Finally, at the distribution stage, the resultant data sets, designed to meet client specified requirements, are packaged and distributed to the various clients by a variety of means.

This is a very general overview of what typically happens. It is important to appreciate that there are other techniques in use or being explored to develop and deliver forecast products for different purposes and users (e.g. Model Output Statistics and Ensemble Forecasts).

Françoise Bénichou – Météo-France (Powerpoint)

The role of the forecaster is very important in the short range. We don't make the end forecast directly from the numerical output. The forecaster has the very important role not only to make the decision on the end forecast but also to choose the synoptic scenario, i.e. the choice of which model will be followed for the final forecast. The forecaster has many different models and model runs to choose from. This has a significant impact on the temperature forecast for the heat wave prediction and heat wave warnings.

Anton Haffer - USA NWS Arizona State Liaison & Forecast office

I just wanted to add that you not only have many models and many runs of those models, but also that some of the models may handle some parameters, say moisture, better than others. The other thing is that you can never get two meteorologists to absolutely agree on anything.

Further comments from the floor (unknown voices)
a) I would like to add something about the quality of the accuracy which depends on how far you are from the normal, i.e., how close you are to the extremes, which in an issue that is important to HHWS.
b) There is debate on what information is important to deliver. There is a lot of confusion on moisture, should we use relative humidity, dew point, or some other measure for it. The jury is still out on the health relevance of moisture. A derived parameter like Apparent Temperature (AT) depends on getting the dew point right.

4. Forecast accuracy: the predictive power (accuracy) of weather forecasts, for weather parameters (especially, minimum and maximum temperature, humidity, cloud cover, and wind direction and speed), for indices based on weather parameters (e.g. apparent temperature), and for overall weather conditions (synopses); special attention to be given to predictive accuracy for very hot conditions, and to the limits of weather forecasts. *Panel discussion initiated by Gérald Vigeant and including Françoise Bénichou, Anton Haffer, Christina Koppe, Glenn McGregor*

Gérald Vigeant - Environment Canada, Meteorological Service of Canada, Quebec Region (Powerpoint)

Gérald Vigeant presented an overview of the historical performance of meteorological models in Canada. With slide 4, Gérald pointed out the steady improvement of around 50% in 36-hour mean sea level pressure forecasts produced by numerical models from the starting point of 1958 to the current year. From about 1980 onward the steady improved accuracy is shown for 12, 24, 36, 48, 60, 72, 96, 120-hour mean sea level forecasts. At the end of the presentation Denis Bourque made the point that we gain about a day in forecast accuracy every decade, that is to say day 4 is now about as accurate as day 1 was 40 years ago in terms of guidance fed to the forecasters. Thus, since we are using 3-day forecasts for the HHWS, the required level of accuracy for such was not available 10 years ago. Gérald indicated that verification has been done for the parameters relevant for forecasting a head wave (Tmax, Tmin, POP, Cloud, forecasts for days 3-4-5 and for days 1-15, and monthly and seasonal forecasts) for 23 cities representing all Canadian provinces. Slide 6 shows the 1984-2005 verification (percent correct = within ±°3C) of the official forecast issued by meteorologists for Today's Maximum Temperature, Tonight's Minimum Temperature and Tomorrow's Maximum Temperature for the four seasons of winter, spring, summer and fall. The slide indicates steady improvement, with summer temperatures showing the best scores. The subsequent slide illustrates that, historically, the human meteorologist outperformed the numerical model forecasts, but that performance edge has been narrowing, especially for day 2 (tomorrow's forecast). Slide 8 illustrates that both the global and regional models have a better ability to forecast maximum and minimum temperatures for hot summers when compared to 'normal' summers (the verification for the June-Aug periods showing the error being totally within the plus or minus 1 range all across Canada). There is strong capacity to forecast temperatures with precipitation forecasts (slide 9) being slightly less accurate. For cloud opacity, the numerical forecasts are only about 60% correct but for wind direction and speed they are up near 90% in accuracy. Dr. Christina Koppe made the point that it should be noted that the accuracy of the models can vary from region to region and from parameter to parameter and it is up to the forecaster to choose which model for which region, etc. Françoise Bénichou of Météo-France indicated that in France they run the same kind of scores (Powerpoint).

Glenn McGregor – King's College London, Dept of Geography (Powerpoint)

Looking at mortality predictions first, Glenn showed a chart of observed vs. predicted mortality for Rome for the summer of 2004 indicating very low correlations (R^2=0.025). Using a 2x2 contingency table, one can calculate a variety of skill measures (Hit Rate, Threat Score/Critical Success Rate, Probability of Detection, False Alarm Rate, Bios) and these show similar poor results. Looking at the observed vs. air mass predicted mortality for Rome, for ages 65 and over for summer 2004 (DT+ days only), also showed a very low correlation (R^2=0.06). In slide 7 the DWD dew point forecast for Rome showed a correlation (R^2=0.36) with that which was observed for 1200hrs. Given that dew point is a critical variable for mortality prediction models there is reason to be concerned. The next slide showed the 6 A.M. dew point forecasts for Paris provided by Météo-France and DWD showing correlations of 0.81 and 0.90, respectively. Scott Sheridan noted that at 6 A.M. the dew point is very near if not equal to the ambient temperature, thus correlations should be higher. Slide 9 showed the variation of Apparent Temperature for various levels of dew point temperature. Thus while the accuracy of dry bulb temperatures may be very good, as evidence indicates, it becomes very critical to get dew point forecasts that are as accurate as possible. So not only is dew point a prediction problem, but apparent temperature appears more sensitive to it as it increases. In his final slide, Glenn showed the weekly mortality estimates for England peaking the week following the heat event of 19 July 2006. Glenn further noted that at about 3 A.M. there could be as much as 9°F between the airport temperature and the temperature in downtown London (Heat Island Effect).

In a question on airport data and the urban heat Island effect, the response from Francesca De'Donato (Italy, Dipartimento di Epidemiologia ASL RM/E Roma) was that the weather prediction is on the airport data but that the health models are constructed to reflect the effect within the urban heat island so that the weather forecast should in fact be for that airport reference station. Scott Sheridan indicated that they studied the mortality data in the Toronto urban area using observation data for all the locations in and around Toronto and got virtually the same correlations except for the Toronto Island airport which has a different micro-climate.

Scott Sheridan noted that the Humidex and Heat Index, liked Apparent Temperature, are more dew point sensitive at higher dew points. Anton Haffer indicated that folks should note that temperatures, being taken largely at airports should be taken as indices rather than the actual value they will experience where they live/work.

5. The meaning and derivation of “ensemble” forecasts
6. Techniques for deriving and examples of probabilistic short and medium-term forecasts, *Ronald Frenette – Environment Canada, Meteorological Service of Canada, National Severe Weather Laboratory - Montreal* (Powerpoint)

Ronald Frenette began with a description of Chaos Theory. The point here is that the atmosphere is chaotic in nature meaning that it exhibits non-linear behaviour. As such, small changes in the initial conditions will generate a different forecast. If it is less chaotic, a major change in the forecast is less likely and consequently we have more confidence in the forecast. If it is more chaotic, a major change in the forecast is more likely and consequently we have less confidence in the forecast. Changes in initial conditions can be due to errors. Imperfect observation coverage such as fewer meteorological observations over the ocean and greater and better quality coverage over populated land areas along with observation errors due to faulty instrumentation or even coding are sources of errors/changes in initial conditions. Even if you have the right data, the analysis can be wrong due to rejection, by the analysis regime, of some of this good data. In the models themselves, there are some imperfections in the calculation methods, e.g. truncation errors, and because the resolution is not fine enough to handle small scale phenomena directly thereby requiring physical parameterization equations, e.g. thunderstorms. Also there are errors that show up in the process due to boundary conditions such as sea surface temperatures, vegetation, etc. which are updated only every week or every month.

Since these errors cannot be completely eliminated, as a solution, it is possible to try to generate a set of results, commonly called an ensemble, using various different initial conditions, using different numerical models, using different physical equations for convection phenomena like thunderstorms, etc. and by modifying some important threshold levels within the equations themselves. In Canada, we run 16 simulations generating 16 solutions. From this ensemble of results one can build a probabilistic forecast. For example, if 8 of these 16 solutions predict rain for tomorrow, the probability of rain tomorrow would be 50%.

In the deterministic approach there is one value or forecast generated, e.g. tomorrow's maximum temperature will be 28°C. In the probabilistic approach, the most probable value is also generated, e.g. tomorrow's maximum temperature will be 28°C but also available will be the probability of a variety of values surrounding the most probable value, e.g. a 30% chance that tomorrow's maximum temperature will be 30°C. In the classical deterministic approach, the user does not have any information on the risk of the maximum temperature reaching 30°C. Thus under the probabilistic approach, the user has more information with which to make a risk management decision. At the end of the presentation Dr. Christina Koppe emphasized the important point that if you have a probabilistic forecast then the decision point for taking action depends on the cost-loss ratio.

In the Montreal Pilot Project for the summer of 2006, a 16 member ensemble with two different models, different equations, and random perturbation of initial conditions was used to come up with probabilistic forecasts up to 16 days into the future for extreme heat

(3 days in a row above 33°C), near extreme (3 days in a row above 30°C), high Humidex (1 day above 40°C) and near high Humidex (1 day above 37°C). For each of these phenomena, the probability was calculated up to 16 days for all of North America generating 64 map displays such as on slide 7. For a single point like Montreal, it was summarised in one table also shown on slide 7. With only 2 cases of high Humidex and seven cases of near high Humidex, the preliminary results for high Humidex show a good signal up to day 8 with some indication up to day 16 but not precise on which day it would occur (+/- 2 days). There were no extreme heat cases.

The ensemble is used for beyond day 4 but for 2008 we will be operationalising the higher resolution regional ensemble and then will have to make the decision as to whether we will use it for days 2, 3 and 4. Montreal Public Health currently uses the deterministic information in their model but is very interested in using probabilistic information in the future.

7. Utility of seasonal climate forecasting for health. *Glenn McGregor – King's College London, Dept of Geography* (Powerpoint)

Glenn McGregor started by stressing that there is a need to think about the issue on a seasonal time scale as opposed to just the usual weather time scale. Forecasts, and associated health forecasts, out to about 10 days are at the outer limit of numerical weather prediction. This limit on the time scale is the critical threshold between preparatory planning and crisis planning. Climate information for lead times beyond 5-10 days is required as there is a need to anticipate events well in advance to get all emergency response systems in place. Assuming we can predict health sensitive climate elements like temperature, dew point, for example with good predictability, accurate health forecasts may be possible. On Slide 3, Glenn showed, based on 25 years of data from the West Midlands, that there is a more or less a linear increase in 65+ years of age standardized mortality, with the number of days of below mean monthly maximum for December. Using a Winter Climate index (zero meaning average, positive meaning warmer with a positive North Atlantic Oscillation and negative values mean colder than average winter for the same 25-year period) in slide 4 Glenn illustrated the inverse relationship with "All-England" mortality. Based on these two slides, there is a suggestion that there are monthly and seasonal health relationships. So the challenge is that if we have these relationships how good are we in predicting the climate on a monthly and seasonal basis. Slide 6, based on 15 ensembles each with different initial conditions, shows that there is variation in the accuracy of prediction of temperature by month and by the time the model is started. Glenn's Slide 7 indicates that the higher the mean maximum temperature for the summer months (example, Paris) the greater the mortality. The second graphic on the same slide illustrates that the higher the standard deviation in maximum temperature (higher variability in maximum temperature) the higher the standard deviation in summer mortality (higher variability in the mortality). Again, this underlines that on a seasonal scale there can be some level of predictability of health outcomes provided there is an acceptable level of predictability in seasonal forecasts.

How predictable was the 2003 heat wave? The ECMWF May 1, 2003 probability forecast for June-July-August for temperatures being in the upper tercile, showed fairly high probability in Southern Europe. This information was potentially very useful because one month before going into summer there was indication of the likelihood of a very warm summer and it would be a good assumption that within this warm summer would likely be some very hot days. So one could use such a forecast to start to prepare and raise awareness. Slide 10 shows the Observed Anomalies for each of the first two weeks of August, 2003 along with forecasts from the Monthly Forecast System. From that forecast system, the 30-day climate forecast did not show much indication, however the 12- to 18-day project started to show it and by 5-11 day days it shows a clear strong signal as did the ensemble Extreme Forecast Index for day d+5 valid for the date of August 12. For the same date, the D+5 forecast of extremely anomalous temperatures from the ensemble prediction system showed >80% probability of temperatures exceeding 35°C almost all across south-western Europe.

Seasonal Climate Forecasts and Health Forecasts: Thus there are clear discernible climate and health associations (monthly and seasonal time scales) and the potential exists for long lead-time health forecasts, at least for summer. Health forecasts for winter may be limited by climate predictability problems being much more chaotic, but summer may be less of a problem. The results from the ECMWF are quite encouraging. It is critical that climate parameters other than the temperature mean are improved; statistics relating to variability are important. There is a need for seasonal climate forecasts models to deliver information from which the likely circulation regime statistics for a forthcoming season can be derived meaning that these models must be able to tell us something about extended periods of blocking, e.g. high pressure systems, that are important for both winter cold outbreaks and summer heat waves and associated health outcomes.

8. The role and experience of weather services in providing forecasts for the health field and others such as agriculture and air and sea transportation. *Denis Bourque, Environment Canada, Meteorological Service of Canada, Business Policy.* (Powerpoint)

Denis Bourque started by saying that the meteorological community has been around a long time helping people manage risk in order to improve the outcomes of their individual activities. There is an increasing realization that forecasts of 100% accuracy are not possible and further that forecasts are not just about severe weather. It is far better to think of the contribution of the meteorological community as a case of helping sectors, including the health sector, manage risk.

As illustrated in the third slide, the meteorological community through environmental prediction covers spatial scales from local to global and covers time scales stretching from one minute to one hundred years, thereby including phenomena from daily local weather and tornadoes, to El Niño and Climate Change.

Hence, meteorological services contribute in many areas of society. In agriculture, the meteorological community helps farmers manage their risk in tilling, seeding, harvesting, irrigation and other activities. As such, forecasts of sunny conditions are just as important as forecasts of rain. At sea, marine forecasts help mariners manage their risks given the serious threats which storms at sea present for life and property.

In Canada, meteorology started as a serious discipline in 1871 as a technological response to a threat. That was when the forecast system was set up following an 1870 Report to Parliament which documented the earlier loss of 235 lives and many ships with cargo. The objective assigned to the new initiative was to reduce risks at sea. At that time, the entire Atlantic coastal area including the Gulf of St Lawrence was considered one forecast area and the forecasts were generated out of Toronto. Science and technology have progressed since then. Currently, this same area is divided into more than 35 forecast areas. Some 50 years later in the 1920's, meteorological services in support of aviation started to "ensure delivery of the mail"; they have since evolved having been found to be critical to efficient, economically sustainable and safe flights. Starting in the 1930's, power plants were asking for forecasts of temperature so that they could plan supply and demand. Today there is an even higher dependence on energy which heightens the associated risks; weather forecasts help manage that risk. Much more recently, the Canadian Meteorological Service began supporting health decisions by introducing biometric indices such as the Wind Chill Index, the UV Index, and the Humidex. Elsewhere in the world, predictive systems are being developed to reduce the risks with other health applications: there is the Malaria Early Warning Systems that provides advice up to a nine month lead time; there is research being conducted on planning demand for services at hospitals and, of course, there is the work on the HHWS which is represented at this workshop.

All of this is about managing risks in a community. So, if I can summarize, what we're trying to do here at this workshop is to define an approach or index which can tell us when the risk is increasing or when it is decreasing so that we can use that information to help the community manage both the health risk and the demand on the health system.

SECTION 2

HEALTH IMPACTS OF HEAT
PART A

9. The epidemiology of heat—the heat-health function: Outcomes measured, morbidity and mortality as a function of weather parameters (temperature and others); who is at risk for the effects of heat; cumulative effects (duration of heat episodes), prolonged effects, delayed effects, effect of when exposure occurs during the summer, effect of joint exposure to weather and air pollutants – *Tom Kosatsky, Mark Goldberg*

Tom Kosatsky – Montréal Public Health Department (Powerpoint)

Tom opened a discussion on the epidemiology of the effects of heat on health. He asked the panel to consider which heat-related outcomes should be measured - direct heat-related deaths, deaths beyond levels expected, or non-traumatic deaths (sometimes referred to as "naturally occurring") above levels expected? If we are measuring morbidity, how is it defined and what are appropriate markers - hospitalisations, emergency room visits, ambulance calls or calls to health-information lines? Whom should we consider at risk for the effects of heat - all people, susceptible populations, athletes, workers?

What mechanisms should be considered - direct (as in hyperthermia), as a contributory factor (as in hot day heart failure), or indirect effects (such as food-borne Salmonella illness, where hot day overgrowth of Salmonella leads to an increased likelihood of infection among food consumers)? What delayed effects do we need to consider – those occurring on the day of heat exposure, those on the following day or two, and/or effects which follow exposure by weeks, months or even years? How do we estimate impacts? Should we do an episode analysis (looking at above-baseline health effects during a defined heat episode) or should we look at the overall heat-health function; if we adopt the latter approach, should we confine ourselves strictly to the summer season or include shoulder (spring and fall) periods? If we look at the heat-health function throughout the year, how should seasonality be considered? Which weather attributes should go into the heat-health function? Should these be limited to temperature (daily mean, maximum, minimum), or include other primary weather variables (humidity, cloud cover, wind or barometric pressure)? Are the other weather variables associated independently with health function or are they linked to health through their influence on temperature? If we consider indices (like apparent temperature) or overall weather conditions (synopses), how important is measurement quality? If correlations exist between weather attributes, how should we handle them? What is the effect of joint exposure to weather and air pollutants? For heat wave analysis, which combination of temperature and duration should we use to define a heat event?

The results of numerous studies analyzing the heat-health function were presented in an overview of the evidence. Looking at the causes of heat-related mortality, in one Japanese study we find heat stroke itself to be only a very minor contributor to the toll of excess deaths (Honda, Ono et al., 1995). Indirect causes constitute far more of the burden of excess hot-day deaths than do causes directly attributable to heat exposure.

As for who is affected, in the Czech Republic, female cardiovascular deaths, as well as total female deaths during heat episodes far surpasses those for males (Kysely, Kriz, 2003). As for where these deaths occur, in a 2006 analysis of 42 US cities, heat contributed to a 10% rise in mortality out-of-hospital (Medina-Ramon, Zanobetti et al., 2006).

The induction period from heat onset to death is relatively brief. The time course of a 1994 Montreal heat episode shows a non-traumatic mortality spike 2 days after the onset of high temperatures (Kosatsky, 2005a). Similar results are seen in a 2002 time series analysis of 8 US cities (Braga, A et al., 2002).

In France, an analysis of the 2003 heat wave displays a high degree of correlation between mortality and both night and daytime temperature (Fouillet, 2006), making it difficult to isolate the effect of elevated minimum temperatures.

The shape of the heat-mortality function tends to be V-shaped in northern cities with an optimal temperature found at the notch and large variability of the mortality effect at the extremes (Jendritzky, 2003). In warm cities, such as Shanghai, the mortality function shows a temperature threshold rather than a V-shape, and also displays substantial imprecision throughout the curve, and not just at the extremes (Kalkstein, 1993).

In a 2004 survey of 12 U.S. cities, there is a very important effect of temperature on hospitalisations, but no additional effect from humidity (Schwartz, 2004) – in contradistinction to many European studies, where temperature has been shown to have a limited effect or no effect on hospitalisations in summer.

Air mass type has been shown to be associated with excess mortality. In Rome, air masses classified as dry tropical and moist tropical plus were associated with excess deaths (Llanso, 2000).

Coincident air pollution on calm days plays a role in the heat-health function and is a contributor to mortality in those over age 65 (Sartor, Snacken et al., 1995; Johnson, Kovats et al., 2005). However, separating the effects of ozone, particulate matter, and excess heat on mortality curves presents technical difficulties given that high temperatures are often associated with elevated pollution concentrations, particularly ozone.

The duration of a heat episode appears to have a cumulative effect on mortality, something that was particularly evident in the data from the 2003 heat wave in France (Fouillet, 2006). A two year survey of excess mortality in Valencia shows that extreme heat episodes which occur early in the season are associated with a greater effect on deaths, supporting the idea that acclimatization has a protective effect (Ballester, Corella et al.,1997).

Has the heat health function changed over the years? A recent Japanese study demonstrates that the optimal temperature (mortality nadir) has increased more than 2 degrees Celsius since 1972, despite a local increase in average temperature of only one degree (Honda, Ono et al., 2006). Studies from Dutch mortality data reveal a levelling off of the sharp V- shaped mortality curve over the past four decades (Garssen, Harmsen et al., 2005). This shows that there has been a lessening of both cold and heat impacts over the years.

Recent heat waves in Spain and Chicago have had a significant mortality effect on the elderly, but negligible effects on people in younger age groups (Palecki, Changnon et al, 2001; Simon, 2005). An Italian study looking at risk factors other than age found that people with pre-existing heart conduction disorders, psychiatric disorders in general, and especially depression are much more likely to die in the heat, as well as people over age 75 (Stafoggia, 2006). Small children are at risk but certainly not markedly, according to an analysis by the CDC (CDC, 2005). Lifestyle and behavioural factors that put people most at risk include social isolation, extremes of body size and percentage body fat, inner-city dwelling, lack of air conditioning, and drug and alcohol abuse (Klinenberg, 1995; Worfolk, 2000).

Delayed health effects have been observed in non-fatal cases of acute heat-related illness Complications of heat stroke include adult respiratory distress syndrome, kidney failure, liver failure and disseminated intravascular coagulation (Donoghue, Graham et al., 1997). Severe functional impairment was observed in 33% of 58 patients admitted with heat stroke during the Chicago heat wave, with no improvement after one year in those still alive (Dematte, O'Mara et al.,1998). Persons admitted to hospital with heat stroke had a 40% lower 20-year survival compared with those admitted with control diagnoses (Wallace et al. 2007).

During the 1995 Chicago heat wave, inpatient admissions for all causes rose dramatically with the heat index (Semenza, McCullough et al., 1999). Although the magnitude of extreme temperatures tends to be amplified in urban heat islands, rural areas too experience heat-related mortality effects, as demonstrated by Rajpal during a 1999 Wisconsin heat wave (Rajpal, Weisskopf et al., 2000).

Among cities in the northern hemisphere, a north-south gradient becomes apparent on comparing the heat-mortality function from 3 areas (Southern Finland, Southeast England, North Carolina). The mortality nadir occurs at a higher temperature the further south one goes (Donaldson, Keatinge et al., 2003).

Differences between Europe and North America can be noted. For heat-related mortality, elderly males in North America are seen as having the highest heat-related mortality risk, while in Europe females rank highest. A higher proportion of hot day deaths are coded as hyperthermia in the US, compared to Europe, and air conditioner ownership is more common in the U.S. Additionally, a heat-related hospitalisation effect is seen in the U.S., but seemingly not in Europe (Kosatsky, 2005b).

What about heat illness in workers? In a time series examining direct heat-related deaths occurring in North Carolina over a 24 year period, of all occupational heat-related fatalities (n=40), 45% occurred among farm laborers, many of whom died unnoticed and without medical attention (Mirabelli, 2005). Heat fatalities among young children have been associated with being left alone in parked cars (McLaren, 2005), and data examining circulatory parameters in children in saunas suggests that children younger than 5 do not demonstrate increased cardiac output as a result of increased temperature (Jokinen, 1990; Guard and Gallagher, 2005). In the Southwestern U.S., a study examining migrant deaths as a result of unauthorized border crossings found environmental heat exposure to be the leading cause of death (Sapkota, 2006).

Mark Goldberg – McGill University, Division of Clinical Epidemiology (Powerpoint)

Mark Goldberg, epidemiologist, studies air pollution and its effect on health. In his initial analyses, weather was always treated as a nuisance factor, but looking at primary weather variables a little more closely, certain associations with mortality become evident. Using Montreal mortality data over a 19-year period, comparing mean percent rise in mortality to a baseline of 15 degrees, and after adjusting for air pollution, there is a rise in cardiovascular and cardio-respiratory disease mortality with higher temperatures. Another striking relationship is observed with levels of air pollution, temperature, and mortality among persons with congestive heart failure living in Montreal. In this population, we found that daily non-accidental mortality increased exponentially for mean temperatures above 20ºC but that the effect was reduced dramatically after adjusting for ozone.

10. Do “heat waves” have a specific health effect? Is it consistent? *Shakoor Hajat – Public and Environmental Health Unit of the London School of Hygiene* (Powerpoint)

Shakoor Hajat led the panel through a presentation of work conducted under a Euro/WHO project which explores the question of whether there is a heat wave effect on mortality. Most epidemiological studies that assess the effects of heat on population mortality employ one of two types of design; heat episode analysis and time-series regression. The heat episode analysis describes health, usually mortality during a specified period, when temperatures are unusually elevated. Mortality given in this period is compared with a baseline, usually derived from the same time period in previous years. Studies of this type have shown notable increases in mortality associated with these episodes. On the other hand, time series regression analyses quantify the heat-mortality relationship throughout the summer, not just during a specific period, and these kinds of studies have shown that in populations with a temperate climate, mortality increases in a general linear fashion with temperature, once temperatures reach a threshold. It is often assumed that the excess observed during a heat episode analysis is in additional to what would be predicted from the standard time-series regression models, but the evidence for this is quite indirect. Is it really the case that the effect of hot days is increased when they occur during periods of sustained, exceptionally high temperature? A related question is what fraction of all heat deaths actually occur during these rare heat wave periods and what fraction occurs throughout the rest of the summer?

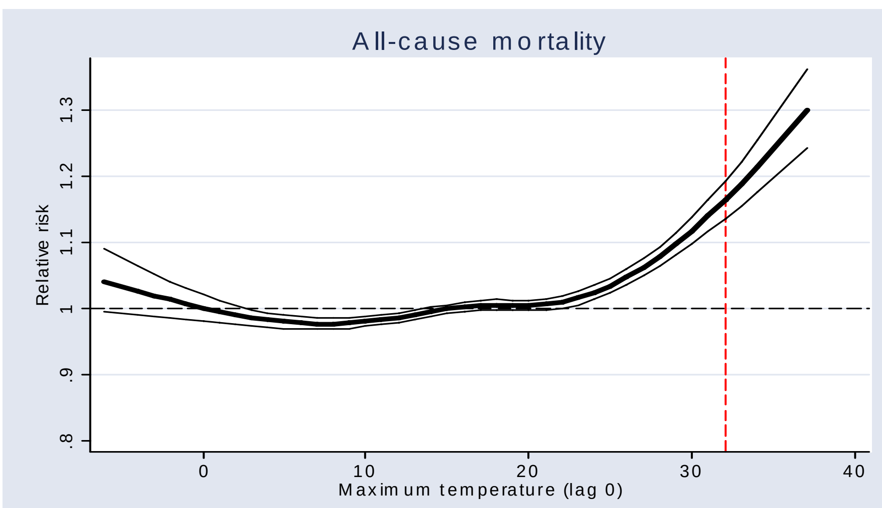


Figure 10.1

To illustrate the second point, one can see (figure 10.1) the estimated relationship between mortality and temperature in London (all cause, all ages). (Hajat, 2006) Along the X-axis are values of maximum temperature on the same day as the day of death, on the Y-axis, is the relative risk of mortality. The dotted line represents 32˚C, the value designated by the meteorological society in the U.K. to trigger a heat warning. One can see that the heat effect begins quite abruptly, around 22˚C daily maximum temperature. It is potentially the case that the slope above 32˚C is steeper than it is between 22˚C and 32˚C, however it is important to remember that there are many more days when these more moderate temperatures are reached, so the actual burden could be greater during the period that the maximum temperature is between 22˚C and 32˚C, than during frank heat waves.

The objective of Dr. Hajat's analysis was to clarify the extent to which conventionally defined "heat-waves" are associated with a greater excess mortality than those predicted from standard time series analyses with smooth curves for temperature. Also, to estimate the fraction of all deaths due to heat which occur during heat waves, a model was constructed using a time-series of daily mortality counts for 3 European cities (London, Budapest, and Milan). Long-term trends in the mortality series were controlled for, as well as season, humidity, and temperature. Then, an indicator (0, 1 variable) for "heat wave", was added. It was this term that was used to quantify the heat wave effect in addition to the effect of temperature. Various factors were considered for the temperature and heat wave terms, depending on the degree of complexity desired. For the temperature index, mean daily temperature was used in the core model; as for lag, temperature on the same day as death was chosen, but an average of the last 3 days mean temperature was considered as well. A linear threshold model was used to model the temperature factor, assuming a log-linear risk above the heat threshold, but splines to model non-linearity were also considered. The heat wave term was defined as a combination of intensity and duration. Intensity was specified as mean temperature above the 99th percentile the whole year with "heat wave" duration of at least 2 consecutive days over that temperature threshold.

For the 3 chosen cities, threshold values were identified. Milan had the highest temperature threshold. In the models without a heat wave term, there was a heat effect on mortality in all three cities. Mortality increased for every 1˚C rise in temperature, from 2.9% to 5.5%. When the wave effect was modelled explicitly, this effect decreased slightly for same-day mortality. In addition, a significant heat wave coefficient was found across the board. When using a non-linear model, the heat wave coefficient lowered slightly, suggesting that there is some non-linearity in the temperature and mortality relationship. When lags were averaged over 3 days, the heat slope itself was still quite strong, but the heat wave coefficient reduced substantially, and in the case of London became negative.

As for the fraction of deaths attributable to heat, overall, and specifically during heat waves, the actual percentage of heat-related deaths is quite small and of that, a much smaller fraction occurs during heat waves. These proportions stayed roughly similar when modelling the linear slope plus a heat wave indicator.

In sum, in all cities, mean temperature was a better predictor of mortality than apparent, maximum or minimum temperature. In lag 0 models, wave effects were apparent in all cities (Milan > Budapest > London). Wave effects were smaller in models allowing curvature, suggesting that it was partly driven by non-linearity. In models allowing for an averaged 3-day lag time, wave effects were considerably diminished and only statistically significant in some cases. The heat effects were biggest for respiratory and cardiovascular deaths. Some contribution of ozone on respiratory deaths during heat waves was noted. Perhaps most significant was the finding that the proportion of attributable deaths occurring during heat-wave is small. In Milan, for example, 1.45% of total (year-long) deaths were attributable to heat, and of that, only 0.24% occurred during a heat wave (specified as minimum 2-day duration of temperature above the 99%). Similarly, in Budapest the percentages were 1.29% and 0.17% and in London at 0.41% and 0.13%

The panel noted that the results of this research draw into question the utility of a trigger for a heat/health warning system. Dr. Hajat agreed that prevention strategies in addition to those in place during a heat wave should be considered. These kinds of strategies may be very different than the mitigation strategies used for extreme heat episodes; they could be longer term strategies, like changes in housing stock. Already, changes in summertime mortality over the past decades suggest that there is a greater awareness of heat morbidity and mortality in the general population and people are taking greater precautions. Dr. Hajat added that although this study looks at all-cause mortality, many heat health functions are based on non-traumatic deaths, based on the supposition that heat can impinge on any disease. Results from recent studies have found evidence to support an effect of heat on external traumatic causes as well (Hajat, 2007).

11. How can knowledge of aetiology inform the prediction of effects: Theoretical and statistical aspects. *Ben Armstrong – London School of Hygiene and Tropical Medicine's Environmental Health Research Unit* (Powerpoint)

Ben Armstrong spoke about how epidemiological modelling will help in the definition of a heat warning trigger. Echoing some of the ideas brought up by Shak Hajat, he again underlined the fact that there is no "natural" dichotomy of days when there is an excess risk of heat-related mortality and days when there isn't. Using the same maximum temperature vs. relative risk scale (see figure 10.1), he reiterated that there is a continuum in mortality risk increase and temperature, where the slope may be smaller on more moderate days, but there are more of them, and consequently, more heat burden. By imposing a classification structure and creating such a dichotomy, if we constrain the system to be triggered perhaps four times a year, there could be some types of models better able to capture heat events with substantial excess mortality. As it stands now, heat risks are spread over too many days for heat watch warning systems to be issued for all hot days, but aetiological research can contribute to choosing the "worst risk" days.

Other weather parameters one might consider in this model could be synoptic systems, humidity, apparent temperature, minimum temperature, maximum temperature, both or neither. Different lag periods could be considered, and some accounting for mortality displacement might be engineered into the model by controlling for mortality deficits in the month following a heat wave. The duration of the event, as well as the timing in the season, and presence of susceptible populations may also be factored into a model. Special warnings could be targeted for specific populations, but this may add an undesirable level of complexity. One topic that has been touched on previously at this meeting is the concern that the forecastablilty of some of these aetiological parameters may be inaccurate, thus giving an inaccurate risk prediction. To date, there has been much conjecture, some presumption, but little hard evidence to guide our decision making on these issues.

Some on the panel expressed their concern that, although interesting from a scientific and methodological perspective, it leaves a perplexing dilemma for public health practitioners who have to make decisions based on science but also based on population perceptions. If we fail to put strategies in place because of scientific uncertainties, we will be perceived as doing nothing during a time of crisis. Public health officials are obliged to act on what they know now, however imperfect the system may be.

This viewpoint was supported by Scott Sheridan who surveyed health behaviour during extreme heat events. His findings confirmed the importance of public perception in changing behaviour in response to the environment. His respondents surveyed reported doing things differently when it was hot, but not necessarily in response to broadcast warnings or heat advisories. He relates that, while setting up a warning system in Seattle, the synoptic system triggered an alarm on a day when the maximum temperature was only 78 degrees Fahrenheit. There was a dispute as to whether calling a warning would risk losing credibility in the eyes of the public, despite the fact that all the criteria for excess heat-related mortality were present. He also cautioned that despite a sharp downswing in summertime mortality over the last century until the 1970's and 1980's, heat vulnerability seems to have stabilized, which may be an effect of greater access to air conditioning. As global temperatures rise, optimal temperatures (temperatures with lowest mortality) rise as well, leading one to question if this effect is due to acclimatization, or simply greater control of one's immediate environment.

The panel were in general agreement that seasonal awareness of heat dangers were a necessary part of the mission of heat health warning systems. The heat health warning system was originally conceived in response to health sector demands to have objective weather indicators to activate a response. More and more, it becomes evident that changing the behaviour of the population should be incorporated as a secondary objective. Changing the behaviour of the population will require a different set of information that includes raising awareness of heat risks, and in this objective, we may already be having some success. Using the comparison of changing smoking behaviour by banning smoking in public, one panel member urged using environmental modification to enforce heat mitigation behaviours.

One panel member brought up the issue of what advice to give for special events. For example, how to avoid excess mortality risks during the Mecca pilgrimage, and "fun runs" in Europe. Physiological studies have found excess adverse health effects from crowding in elevated temperatures, and deaths during even modest heat elevations have occurred during "fun runs" in the U.K. One panel member reported that giving bottled water and using mist cooling systems is carried out in Philadelphia during public sports events.

Another concern was expressed in relation to the political implications of heat health warning systems, given that heat-related mortality may be actually greater on non-heat wave days. Are the "silent majority" of heat-related effects being addressed by the current systems or do the systems serve preferentially the needs of officials who want to be seen as doing something in the face of a crisis?

SECTION 3

THEORY OF HHWS

12. The nature of warning systems. *David Buckeridge – McGill University, Dept. of Epidemiology, Biostatistics and Occupational Health.* (Powerpoint)

David Buckeridge prefaced his remarks with the caveat that he is a methodologist in the informatics of surveillance, rather than a specialist in HHWS.

A warning system should provide an accurate and timely indication of an event in order to inform action. The essential aspects are prospective analysis, sequential decision-making and a link to action. There are three fundamental components of such systems: 1) ongoing data collection and processing; 2) analysis and interpretation of data; and 3) decision making and intervention. It is important to realize that warning systems are ubiquitous, and many methodological issues are similar across the various domains that employ warning systems (Lombardo and Buckeridge, 2007; Wagner, Moore et al., 2006).

In terms of defining a HHWS, the accuracy and utility of the system follows from the event definition: what event, exactly, is the system intended to detect? The range of systems currently in place exhibits some heterogeneity in the event of interest. For example, sometimes the event of interest is the meteorological context associated with increased morbidity or mortality, and in other cases it is an unexpected increase in mortality or morbidity. It is important to be clear at the system level about what it is that the system is meant to detect and what are the determinants of that event. Thus, it is helpful to have a conceptual model that describes the event of interest, the determinants of the event, and the relationship between the determinants and the event. This model should reflect explicitly what is known about the event and its determinants, ideally defining causal influences and strengths of association. If this step is omitted, the consequence is a lack of clarity that is often propagated throughout the use and evaluation of a warning system.

Practically, most of these systems operate using data and composite measures that are collected for reasons other than for use in a warning system and these data may provide only an indirect measure of the event of interest, which remains unmeasured. There are two basic modes of acquiring the data: 1) in a batch mode with summary files covering a temporal interval received at regular intervals; and 2) in a real-time mode with data transferred to the system immediately after the data are recorded in another system. The mode of data acquisition can affect data quality. For example, temporal delays in reporting occur in different ways with batch and real-time data acquisition. Missing or dropped data, data errors, and changes in the coding scheme, are other issues in data acquisition that can affect data quality.

The next step in the process is the analysis. The fundamental task in the analysis is, given a statistical model of what we expect and the observed data, to determine the probability of the event now and, more importantly, the probability of the event occurring in the future. The statistical model of what we expect to see should be consistent with the conceptual model. Historical data are usually required to estimate parameters for the statistical model. In many warning systems, including those developed for extreme heat events and for bioterrorism, the events of interest are rare. As a result, there are few historical data available from events, so the statistical models usually reflect what we expect to see during a "non-event" and data from "non-events" are used to estimate parameters for the model. The null hypothesis implicit in this approach is that there is a "non-event" and the alternative hypothesis is that there is not a "non-event", which is sometimes referred to as the omnibus alternative hypothesis (Waller and Jacquez, 1995). In other words, an alarm indicates some deviation in the observed data from data observed in the absence of an event, but an alarm does not provide any specific information about the nature of the event.

Many statistical methods have been used in surveillance and detection systems. Relatively straightforward statistical process control methods, including cumulative sums and moving averages are very popular in the manufacturing industry and more recently in some public health systems (Hutwagner et al., 2003). These methods are used most frequently for surveillance of univariate data streams that don't posses any systematic variation. Some authors have described the use of generalized linear models, with Poisson regression used frequently for surveillance of count data (Farrington & Beale, 1993; Kleinman, Lazarus et al., 2004). Temporal and space—time scan statistics are also used frequently in public health systems (Kulldorf et al., 2005). It has been shown rather clearly that in warning systems where the data are ordered in time and where decision making is prospective, that accounting for the temporal autocorrelation of observations and for the systematic variation in the data both improve the accuracy of event detection (Reis, Pagano et al., 2003). So, for example, time-series models and distributed-lag models that allow one to predict a variable from not only the historical value of that variable but also from certain values of other variables, possibly at different temporal lags, generally tend to improve prediction detection performance as compared to models that ignore the temporal nature of the data. In addition to time-series methods, some warning system researchers have also applied models drawn from computer science, including dynamic Bayesian network models (Sebastiani et al., 2006), and hidden Markov models (Le Strat and Carrat, 1999).

Since warning systems are used to inform action, it is helpful to view these systems as a facilitating decision making under uncertainty. A decision is an irrevocable allocation of resources (Raiffa, 1997), and doing nothing is a decision. In this framework, the objective is to identify the optimal decision given: 1) the costs of events and actions; 2) the effectiveness of actions or interventions; and 3) the probability of events. If all three of these elements are know, then one can use decision theory to identify the optimal decision in any setting, accounting for the uncertainty inherent in the observed data. In a dynamic setting, partially observed Markov decision processes (POMDP) can identify the optimal decision-making policy under all possible situations (Izadi and Buckeridge, 2007). The main limitation of using decision-theoretic and POMDP methods is that it is difficult to quantify costs, effectiveness, and event probabilities. For interventions in particular, the effectiveness is often not known quantitatively.

A few frameworks exist for evaluating public health systems in general, and the foci for evaluation are reasonably well defined. Frameworks developed by the CDC (2001) as well as those based on the DeLone and McLean model of information system success (Delone and McLean, 1992) are the best known. These frameworks all extend beyond the issue of statistical event detection and consider factors such as information quality, system quality, user experience, and system benefits. A consistent finding from implementing information systems in general and in health related settings in particular, is that the technical performance of the system is only one of the many factors required for a successful system (Lorenzi et al, 1997).

To summarise, warning systems are used in many application domains and it is important to consider what others have done, and what others have learned from building, operating and evaluating systems in different areas. Conceptual clarity about the event of interest and its determinants is important from the outset of system development, but this conceptual foundation is often overlooked and the consequences propagate, complicating interpretation of system output and system evaluation. A wide range of analytic methods have been used in warning systems and many of these methods are likely to be appropriate for use in a HHWS. Finally, while evaluation of warning systems can be challenging, existing evaluation guidelines for public health systems should help in evaluation efforts and it is important that evaluations consider more that just the statistical aspects of event detection. In particular, evaluations should consider the impact of systems on decision-making processes, public health actions and population health outcomes.

13. Objectives for a HHWS. *Mathilde Pascal, Scott Sheridan, Christina Koppe, Anton Haffer, Francesca De' Donato*

Mathilde Pascal - Institut de Veille Sanitaire, Département santé environnement (Powerpoint)

In France, the national health warning system is designed to prevent mortality during heat waves; it is believed that both the resulting short-term mortality reduction and the long-term stimulus to adaptation, justify the warning system. During and before 2003, the prevention and adaptation measures in place weren't sufficient for some extreme events so a goal in designing the warning was the identification of those extreme events. The general objectives of the system are: 1) to identify when and where a heat wave is likely to happen, 2) to identify if this heat wave presents risk, then, 3) to warn the public authorities who are in charge of the action plan and finally, 4) to detect early impacts on the health of the public. The first three are accomplished by monitoring bio-meteorological parameters. The last objective of detecting the public health impacts early is done through monitoring of real time mortality and morbidity data.

In 2005, France collected examples of objectives from various countries. In Quebec and France the objectives are specific and relate to the prevention of a specific level of excess mortality over three days or longer, while elsewhere (UK, Hungary, Germany, Portugal and Italy) the objectives are more general such as to reduce expected deaths or reduce/prevent summer mortality due to heat.

Some practical issues should always be considered: Are we interested in a heat warning system or a heat wave warning system? (heat wave meaning something unusual); what is the actual level of risk that the system is intended to avert? Who are the population subgroups targeted? How many days in advance should the information be provided to allow for effective intervention? The risk of being wrong in giving the warning increases the further you go into the future. There are ethical, political and social consequences, so we need to define the objectives and the scope of the system, 1) with the stakeholders and within the action plan; 2) include specific organizational or ”logistic” objectives, and 3) try to use quantitative objectives as much as possible with a view to evaluating the system.

Scott Sheridan – Kent State University, Dept of Geography

A lot of the objectives are similar across all systems. One objective would be to stress communication among stakeholders to make sure that all the local and regional players are reacting similarly. Often you have very different structures or no structure at all, so it is important try to make sure that all the important agencies are in communication with each other. One of our objectives is to make the data transfer as transparent and easily accessible as possible. Another objective is to properly convey the sense of risk of heat to the overall population. There are problems with making precise mortality forecasts. The verification is poor because there are a lot of random fluctuations in mortality that have nothing to do with the weather. It's only in the longer term that verification works (e.g. the Philadelphia study). The objective then, rather than predicting mortality, is to try and convey on which days the risk is most significant. Thus the effort is to try to balance out the thresholds used to call warnings, so that we call them for the correct days.

Dr. Christina Koppe – Deutscher Wetterdienst

When setting up a heat warning system you should be clear as to the objectives for your system, as they can vary significantly. One point is: what do you want to prevent? Do you want to prevent heat related morbidity, or mortality, or both. What fraction of this heath impact do you want to prevent: do you want to prevent only increased mortality or all heat-related mortality? There is the danger that nobody will listen to your warning if you release it on every summer day. You should be clear on how timely the warning needs to be. This depends on the health system. Do you need your warning one day in advance, two days in advance? etc. It is very important in setting up your system to know what you want and need. You cannot use a very complicated indicator if you need a warning five days in advance. Then there is the question of the resolution of your system. Do you want to have a system for a city, for a region, or an area of several regions with different warnings levels? Another important point is what information do you need and what information do you want to disseminate. Do you issue a warning, or do you want to quantify the risk? And if you just communicate the mortality impact to health care professionals one risks not having them take further warnings seriously because the studies based on a large population may show no effect in a small region. Developing a system where the mortality temperature relationship is based on mortality data from densely populated areas presents problems of accuracy for a rural area or a small area.

Anton Haffer - USA NWS Arizona State Liaison & Forecast office

Most of the important things have already been said. As public servants, the public is consciously or subconsciously expecting us to protect them at all times, 24/7. Coming from a hot climate, the problem that heat poses is something that people don't recognize since they take for granted that it's hot: the issue is to tell people it's not business as usual today, that they need to do something differently, whether it's as a human being in a family or as a manager in a company. In our area, where we have these ridiculously hot temperatures, some people have no choice but to go outside, e.g. landscapers, carpenters, police, postal workers, etc. Do they change their method of operation on extreme days? Probably not. The objective is to tell them that today is not the same normally hot day and they need to pay attention, drink more fluids, limit the times the crews are out in the field, staff up the emergency rooms, perhaps even close schools if they don't have air-conditioning or cancel schools' sporting events. So the objective is to increase awareness of a problem to which little attention is paid. The objective here is behavioural modification out of that equilibrium mode and here we need to show some leadership as government employees.

Francesca De' Donato – Dipartimento di Epidemiologia ASL RM/E Roma

There are a lot of different systems in Europe which essentially do the same thing while employing different methods. But the key thing that is brought up often in setting up your warning system is that it is not only the complexity or the methodology that is important, but the reality of the local situation as well. So a warning system can be slightly different for a big city like Rome, with the warmest city climate in Europe, but also different in terms of public health. These realities should be taken into account as well when actually designing a system. You can have different threshold levels for different cities. It is also important to consider the timing of when the warning comes out. For a warning coming out late in the afternoon there is not much one can do on that particular day, because it's far too late. The social and health services won't have the time to do anything, and the hottest hours of the day will have already occurred.

In Italy, there are three levels of warnings. The first level is a pre-warning indicating elevated temperatures but not yet constituting a risk. Then when level 2 and level 3 come into play, the agreed upon intervention activities are put into place. In Italy in summer, most people go on holidays so there are fewer people around, including doctors and nurses. So if there is going to be a heat wave, authorities must plan for it many hours in advance, at best a week, or days at least.

14. What decisions are made on the basis of HHWS predictions, and how and when are they made: needs for decision-making under uncertainty; are there different information needs for health departments, civil protection authorities, and the public. *Monica Campbell, Eliane Raymond, Diane Desjardins, Jason Samenow*

Monica Campbell – Toronto Public Health Department, Environmental Protection Office (Powerpoint)

Monica Campbell spoke about heat health warning systems from a municipal perspective. Until now, the discussion has focused on communicating with service providers and with vulnerable populations in order to influence individual behaviour, but there also needs to be some consideration given to shifting the behaviour of decision-makers. Our role in public health is to shift the policy debate by giving input at a municipal and sometimes a provincial level to open a dialogue on how to create more sustainable systems and environmentally balanced use of land. We have to think about climate change and HHWS in the context of massive urbanization. Large scale aspects of urban planning and the future of global design have been addressed by creative groups such as the *Institute Without Boundaries* and others involved in finding solutions and bringing technologies to bear on massive global urbanization issues. How can something like a HHWS help with that effort?

Whether related to sprawl or higher urban concentration, massive urbanization is a global phenomenon and it is associated with a health risk. With a population of 7.8 M people in 2001, Toronto is the fastest growing urban area in Canada. Population is projected to reach 11 M in 2031. A surrounding green belt comprised mostly of farmland and natural areas protects 1.8 M acres. Efforts are underway to control where and how growth occurs. Although emissions per capita from automobiles and industry are greater with sprawl, the risk can be greater with denser urbanization, since people are brought closer to hazards. Smog and heat problems are compounded in cities because vehicles and people are in close proximity**.** Additionally, the canyon effect of buildings traps pollutants**,** causes urban heat island effects, and extensive roads systems contribute to heat retention in cities**.** Local emissions compound transboundary pollution**.** Exposures are elevated during commuting (whether walking, cycling, waiting for transit, or inside a vehicle in stagnant traffic).

Statistics documenting hot weather related mortality over the past 50 years show great variability, making it difficult to describe a “typical” year. While heat-related mortality shows a linear association with duration of heat episodes, the vast majority of extreme heat events are short – most last one day. Reducing the adverse impacts of climate change and smog, such as through warning systems for the public aimed at exposure reduction are one strategy used by the Toronto Public Health Department.

Some broad issues for discussion include - can a consistent HHWS be developed for use across Canada? Can we develop a consistent heat response protocol that is based on best available evidence? Can we connect public concern on high heat days to mitigation actions? Other issues to consider include - what is the potential for ‘green building design’ to reduce air conditioning needs? What are the best health protective messages, given concurrent smog? How do we reach and advise vulnerable or marginalized populations? Outdoor workers? And lastly, is there a maximum indoor temperature threshold? Currently, Toronto officials are using 32˚C, but evidence for this threshold is largely a matter of conjecture. In dense urban areas, residual heat in non-air conditioned buildings can prolong elevated indoor temperatures even after a heat alert has been terminated. Input from staff managing heat response programs have underlined the need for a less complicated system for communicating health risk. As well, there is a need for better predictive capacity for multi-day events as it affects operations of hundreds of partner groups (social/community). There is also a need for Environment Canada to commit resources for weather data to ensure that alerts are plausible and accurate, and a need for clarity on the role of public health versus social agencies. Finally, we need to determine when a program should shift to emergency response.

Éliane Raymond – Ville de Montréal, Centre de sécurité civile (Powerpoint)

Éliane Raymond outlined the intervention plan in Montreal's heat watch warning system. The general objective for the plan is to prepare and devise interventions to be implemented by the boroughs and municipalities of Montreal. More specifically, her team relays the 'alert/intervention levels' coming from the Montreal Public Health Department (DSP) to the boroughs of Montreal and to the other municipalities on the Island of Montreal and ensures that the required intervention measures are put into place efficiently.

The link between the DSP and the Emergency preparedness organization of the agglomeration of Montreal (OSCAM) depends on the time of year and the forecast sent to the DSP by Environment Canada. At the start of the summer season, the DSP's parent organization emails the OSCAM to signal the beginning of a seasonal watch. During the season, when the Health Department receives a heat warning from Environment Canada (forecast of T˚C≥30˚C and Humidex of 40 or more), a notice is sent to the OSCAM to intensify surveillance.

When extreme heat indicators are forecast (3 consecutive days with an average T˚C max ≥ 33˚C and an average T˚C min ≥ 20˚C or 2 consecutive nights with T˚C min ≥ 25˚C), an **alert** level is signaled to the OSCAM and the local health and social services centers. The Emergency Preparedness Coordinator of OSCAM along with the DSP organizes a conference call with the coordinators of the non-governmental organizations involved in relaying messages on extreme heat to the public and the general directors of the boroughs and other municipalities in order to inform them of the change in the mobilization level and to enable them to prepare for the next level of mobilization (the intervention level).

The **intervention** level is triggered by extreme heat indicators that reach the predicted levels specified above (alert level) or by excess numbers of death or emergency room consultations shown by daily surveillance data during this period. The planning of intervention measures is done by first sending an e-mail notice of a heightened level of preparedness to the Emergency Preparedness Coordinator and by organizing a conference call involving the DSP and various partners, including the Emergency Preparedness (EP) Coordinator, the duty officer of the EP Center and the Director of the EP Center. Those responsible for other municipal departments are put in touch with the emergency coordination center via the duty officer. Finally, the general directors of the boroughs and other municipalities are informed of the situation and advised to put their intervention plan into effect.

The intervention plan includes the following:

- opening of air-conditioned cooling shelters (community centers, libraries, arenas, schools, etc.);
- prolonged opening hours for public swimming and wading pools and water games;
- supplying of water bottles, juice, popsicles, etc to those who need them.

The cooling shelters are open to those who can get there on their own and to those who need transportation provided by the municipal and borough authorities. Such a procedure requires the development of effective communication tools to reach and inform citizens. OSCAM is also working in collaboration with non governmental organizations, the DSP and its parent organization towards the elaboration of a door-to-door protocol aimed at the identification of vulnerable people who could need transportation to the cooling shelters.

Demobilization and **recovery** are similarly coordinated.

Diane Desjardins – CSSS de la Montagne (Powerpoint 1 and Powerpoint 2)

Diane Desjardins, Health Promotion and Prevention Advisor, and local coordinator of emergency measures of CSSS de la Montagne, (Montreal-based Health and Social Services Centre) elaborated on local level actions for heat health warning systems. Preparatory work to identify the vulnerable clientele and planning a list of personnel to be called back in case of an intervention is a key element of the groundwork that needs to be considered in advance.

Environment Canada emits a heat warning at 30˚C or more and 40 Humidex or more, these warnings are automatically transmitted to the CSSS and the information is shared with all personnel concerned. These warnings are conveyed to a social service agency which informs non-mobile vulnerable clientele of their possible transfer to a cooling shelter if the situation deteriorates. The warnings suggest that mobile vulnerable clientele go to cooler places for at least 3 hours a day if the situation reaches the intervention level, and informs vulnerable clientele who cannot be transported of the necessity to increase monitoring for signs of dehydration.

A heat alert (based on a 20-year retrospective analysis of the actual mortality experienced in Montreal) is called when an average of both maximum temperature of 33˚C or more over 3 days AND minimum temperature of 20˚C or more over 3 nights is forecast. A prediction of a minimum temperature that does not go below 25° C for two consecutive nights also gives rise to a heat alert. Rapid communication on a regional and local level and contact with municipal, volunteer and transport resources begins a process to prepare transfer of vulnerable, mobile clientele to cooling shelters if and when necessary.

When actual conditions meet public health criteria or excess deaths or ER consultations are reported, mobilization of CSSS resources puts local intervention plans into effect. Vulnerable people are transported to cooling shelters, where they can obtain relief from the heat and be closely monitored for potential signs of heat stress (behaviour changes, agitation, sleep disturbances…), and nursing or psychosocial support can be offered. Those who can not be transported may be monitored for signs of dehydration and referred to treating physicians for problems related to medication use.

Jason Samenow – U.S. EPA Office of Atmospheric Programs Climate Change Division (Powerpoint)

Next, Jason Samenow presented his work on the development of an Excessive Heat Event (EHE) Notification and Response Guidebook. The guide was developed by the Environmental Protection Agency with the goal of providing local public health officials and others with convenient access to critical extreme heat event information, options for defining EHE conditions, and guidelines on how to assess local vulnerability to EHEs. The guidebook provides a “menu” of public education, notification, and response actions to consider when developing or enhancing an EHE notification and response program.

The potential public health impacts of excessive heat events (EHEs) warrant that they receive the same level of response planning as other extreme meteorological events. A failure to plan and respond is an invitation for a potential public health disaster. EHEs can be accurately forecast several days in advance and either established EHE programs can be implemented or effective ad-hoc responses initiated. EHE programs use existing staff and resources, thus minimizing costs for potentially significant public health benefits.

The EHE guidebook, released in the summer of 2006, was developed as part of a collaborative effort with federal partners, such as the U.S. EPA, National Weather Service (NWS), Centers for Disease Control and Prevention (CDC), and the Department of Homeland Security (DHS). Working alongside these agencies were key subcontractors and consultants, such as Stratus Consulting Inc. and Laurence Kalkstein, Applied Climatologists Inc., as well as a technical working group made up of staff from U.S. EPA, NWS, CDC, DHS, Toronto Public Health, Philadelphia Department of Public Health, and Energy Coordinating Agency of Philadelphia. Independent external reviewers examined drafts and incorporated comments. A literature review and synthesis of current EHE notification and response programs was studied with past and current staff.

Recommendations addressed in the guidebook include: EHE definition and forecasting, public education, response preparation and actions, and EHE program review and evolution. The pros and cons of choosing either a fixed or relative threshold for warning levels are discussed in defining EHE conditions, as are recommendations for relying on local weather information.

Recommendations for public notification and education suggest using a mix of media (television, radio, internet, papers, etc.) and incorporating detailed anticipated onset and severity of the EHE, as well as defining those at greatest risk (e.g., young, old, homeless), and describing appropriate responses. These responses should include spending time in air conditioned locations, staying hydrated and checking on vulnerable persons. Information given to the public should include appropriate use of portable electric fans (vent hot air from rooms or draw cooler air in) and should describe how to access additional information (provide toll-free lines to report health concerns).

The guidelines for response preparation propose understanding local constraints and opportunities. It is advised to develop a plan and clearly define roles and responsibilities with critical service providers, such as public health departments, emergency medical services, offices for the elderly, homeless shelters/advocates, public utilities, and persons with strong ties to vulnerable individuals and populations (e.g., religious, ethnic, and community leaders).

Intervention actions for extreme heat event responses must encourage use of, and facilitate access to, air conditioned buildings (shopping malls, libraries, movie theatres, senior/community centres), prioritize direct assessment and providing services to those at greatest risk (daytime homeless outreach, nursing home and senior housing visits, and extra staffing of emergency medical services). Re-allocation of available resources for EHE needs might include shifting public health staff from inspections to assessment of at-risk populations and locations. Suspending utility shut-offs is another key element in the response plan. The EHE program should be regularly reviewed and updated at the end of the season to evaluate both successes and areas for improvement by program partners. Contact may be made with other EHE program partners to discuss their issues and responses.

While guidance has been developed to reduce the risk posed by excessive heat events, the most vulnerable groups do not always receive critical, life-saving information. The analysis of spatial patterns of vulnerability shows promise for targeting intervention to at-risk groups. A new pilot project is underway which uses geographic information systems (GIS) for this analysis. The project was initiated through the Weather and Society Integrated Studies Program (WAS*IS) (funded by National Center for Atmospheric Research, see: http://www.sip.ucar.edu/wasis/) which employs new tools and concepts to bridge the gap between physical and social sciences, particularly in the fields of meteorology and climatology. The idea is to map biophysical and social indicators related to vulnerability to adverse health outcomes from excessive heat. Overlaying these indicators allow for identification of "hot spots" or areas of elevated risk from excessive heat. A map of heat-related risk developed for Philadelphia reveals that the high-risk areas predicted by the vulnerability analysis coincides with the locations of most of the heat-related deaths from the 1999 heat wave in that city. An analysis is also underway for the city of Phoenix, Arizona. The team conducting these spatial analyses (from the U.S. EPA, National Center for Atmospheric Research and the University of Wisconsin-

Madison) hopes to publish these results in a peer reviewed journal in the next year. (Slides 5 and 6 in Montreal2006-WASIS1.ppt – see Appendix A – provide some more information and an illustration on this project).

15. What do Canadian cities look for in a HHWS? *Ian Blanchard, Lorie Greco, Norman King, Martha Robinson, Sandra Roman, Christiane Thibault*

Ian Blanchard – City of Calgary, Emergency Medical Services (EMS) (Powerpoint)

Calgary doesn't have an elaborate heat warning system. EMS is responsible for the provision of all pre-hospital care in and around the city of Calgary. Calgary is a provincially-funded medical region so the province is in charge of all the hospitals and emergency departments and the Municipality generally is in charge of ambulance services.
Calgary does not have a specific heat response plan. Calgary does not get a lot of hot weather. EMS informs the public of prevention strategies when the media reports the approach of “hot” weather. There is no explicit trigger point for the system. Generally, the public education officer, whose full-time job is prevention and educating the public on not injuring themselves or getting sick, will go on the media or on a media campaign to advise people what to do. When we know that hot weather is approaching we consider the effects on hospital time, i.e. the time that it takes for paramedics to offload their patients in the emergency departments. EMS has also begun data collection that will be used to create a model to predict resource requirements at an annual parade (the Calgary Stampede Parade attended by 400,000 people) which is held at the height of the hot season. Future needs for the Heat Health Warning System include being able to predict increases in patient volume (e.g. offloading patients), knowing high demand times and also informing the public a little more in advance. A long-term change in their behaviour is required along with better preparation and deployment of staff and operational vehicles (e.g. with air conditioners working) for hot weather. There is a requirement to anticipate resource requirements so as to maintain normal operations for special events.

In terms of heat health challenges for Calgary, multiple variables are going to influence the outcome. It is difficult to measure one overall outcome, as parts of it are measured by different organizations, thus making it hard to understand the relationship between the heat wave and the outcome. So it's difficult to know when there might be a problem. Calgary has low average summer temperatures with the occasional hot period, and has relatively low humidity. Temperatures often decrease at night due to the altitude so there is some relief from the heat. Nevertheless, there is a large heat island effect. Calgary has just reached one million in population and is increasing about 30-50,000 per year with increasing density in the centre-city area including a sizable indigent population who have escaped the boom in the economy. Like most places, Calgary has an aging population.

Lori Greco – Region of Peel Public Health, Chronic Disease & Injury Prevention Div. (Powerpoint)

Peel region is just west of Toronto; the population is a little over 1 million. The Region includes the Municipalities of Brampton, Caledon and Mississauga that are a mix of urban and rural sectors. Historically, Peel called its heat warnings when Toronto called alerts. The data that was collected for Toronto’s alerts was from Pearson Airport which is situated in Peel Region so at the time there seemed no reason to have a Peel-specific system. In August 2005, the Region of Peel Medical Officer of Health struck a task force to determine if there was a need for a system specific to Peel. The task force included representation from social services, community agencies, the health department and the municipalities in the region. The task force developed a work plan that included reviewing existing extreme heat response models and warning systems and reviewing evidence for best practices for response and warning systems. The task force also looked at what the current response of stakeholders in the region was, specifically what various agencies and groups were doing; for example, what the emergency responders were doing. Dr. Larry Kalkstein conducted research to look at what the heat health relationships were over a 14 year historical period to determine whether a Peel-specific alert system was warranted. The research found that the 'match' with Toronto and Peel alerts was low; that there were excess deaths for all three municipalities within the region; that there were different conditions within the region; and a threshold-based tiered alert system was recommended. In the fall of 2005 all of the community stakeholders were brought together to review and assess the results of the research. Recommendations were developed and presented to the MOH and to the Regional Council. Following this, a new warning system was developed, and communications were enhanced including developing new resources and a new website. In the spring of 2006, the community stakeholders were brought back together, the new system and resources were launched and the stakeholders discussed enhancing and coordinating response activities. Key communication messages included "stay cool, stay hydrated and check on your neighbours" and communications and resources were built around those messages. The Alert Notification shown in slide 6 goes out by fax and e-mail to all stakeholders. The Alert Notification indicates both the current status and the prediction for the following day, which is something the stakeholders strongly stressed was needed. A visual identifier was developed along with a dedicated website www.hotweatherinpeel.ca and announcements for alert and extreme alert are made. Information on heat and health was revised for the website. Heat / health guidelines were developed and distributed to 8 different categories of community stakeholders and vulnerable groups including the public, schools, agencies serving the elderly, landlords and housing, daycare centres, recreation departments, outdoor workers and homeless shelters. The guidelines include general information on what to do in hot weather and on what's different during a heat alert and during an extreme heat alert. They indicate what to do that's different and provide information on signs of heat over exposure and on treatment for heat ailments. The alert notification goes out the day before the heat event and is locale specific, so it speaks to the area within the region that it's intended for and it indicates severity, i.e. whether it is heat alert versus extreme heat alert. A 24 hour information line is available, including an after-hours message that links to Telehealth Ontario for heat health information. On an on-going basis, an effort is made to work with GTA partners through the Medical Officers of Health (MOH) including Toronto Public Health, to align language in terms of heat alert and extreme heat alert and other messages. For ongoing review and revision of the plan and response activities, stakeholders will be brought together again in the fall of 2006 to review response and explore what changes can be made. A formal evaluation is being done that will determine whether the public heard the alert and what they did; whether stakeholders heard the alert and what they did; and to determine the effectiveness of the alert system in predicting deaths and (in the longer term) saving lives.

In the future, some of the issues that might be considered to improve response are: what the minimum response standards should be nationally, for example what are minimum communications that should go out?; how to focus on vulnerable populations and what's the very minimum that we might do to support them?; the need for consistent language among various alert systems; coordination of heat messages with other messages, including smog messages; and public policies on what level of activity and response is appropriate. Another challenge is media messages that cross jurisdictions and keeping messages consistent across jurisdictions.

Norman King - Direction de Santé publique de Montréal, Environnement Urbain et Santé

A five pronged approach is proposed for what Canadian cities look for in a HHWS: 1) 100% reliable; 2) easy to implement; 3) low cost; 4) saves lives; and 5) reduces morbidity. The relationship between Montreal with neighbouring colleagues from Laval on the north and others to the south during a heat warning, alert or intervention needs to be considered, as the media tend to come to Montreal and therefore what we say has an impact on our neighbours which therefore requires a lot of collaboration amongst us. The difference between warning and alert needs stressing because a lot of energy is expended in the warning and even pre-warning stages … getting the population ready, getting neighbours ready, and getting families ready to check up on the elderly and the vulnerable. A lot of preventive work is done during the pre-warning and warning stages.

Martha Robinson – City of Ottawa Public Health Branch

Ottawa has had a HHWS since 2003. We have a wish list. Ottawa's wish list includes an evaluation of existing systems to tell us whether we're even doing the right thing by looking exclusively at the Humidex reading, which might not be the best indicator. We would like somebody to say: “here are all the systems”. A list of best practices that are evidence-based is needed and not just a list of what everybody else does, because Ottawa wants to pick the ones that work. Ottawa wants a list of what is actually working and having a positive effect. Train the trainer manuals are required that could be given to intermediaries... if these were developed at a national level, we could give them to landlords, social workers and outreach people. Also 30 second public service announcements need to be developed that could be broadcast on radio and television.

Sandra Roman – Laval, Quebec Public Health Department

About 350 thousand people live in Laval, just north of Montreal, with slightly above average socio-economic status. Like everywhere else, Laval has its own heat island pockets, poverty and aging populations; so these issues have to be addressed. A big proportion of the Laval population commutes to Montreal every day and listens to the same media, so any heat alert going on in Montreal will, of course, have an impact on our population. A challenge of being in a smaller region, as compared to Montreal, is in the collection of surveillance data in that mortality data is fairly easy to obtain, but morbidity data comes from multiple sources, resulting in difficulty getting information, especially on weekends and holidays. An advantage of being in a smaller community is the close working relationship with community leaders, since contacts can be made easier. Laval has a model that suits its needs well. Of course the need is to be sensitive enough to predict extreme heat waves that would have major impacts on population, but not so sensitive as to create too many false alarms which quickly would have major impact on credibility with the population and our partners. Yes, improved accuracy would be interesting and the more complex models look appealing, but in the context of limited resources, at least in Laval, we would not want that to be at the expense of simplicity and acceptability by the people who have to work with these models. Timeliness and simplicity are also very important, particularly when we don't know to what extent a more complicated warning system is actually going to change the outcome in terms of mortality. Laval is working very hard on long term interventions such as public and professional education, targeting interventions with our local authorities, especially in the heat island issue; proper urban planning and improvement in the health care infrastructure.

Christiane Thibault – Direction de la santé publique de Montérégie

Montérégie is the second most populous region after Montreal with 1.3 million inhabitants spread over 11,131 km^2. The region is situated south of Montreal Island, on the other side of the St-Lawrence River. The region is a mix of urban, industrial and rural areas. The population is divided into 180 municipalities. The majority of the population is found in the area surrounding Montreal.

Our HHWS is based on criteria developed by the Montreal Public Health Department. Actually, all of the regions bordering on the Montreal region, such as Laval, the Laurentians and the Montérégie, have collaborated to use the same criteria and decide together on the intervention phase (alert or mobilisation) when a heat wave occurs. However, the public health interventions are quite different in each of these regions. For instance, in Montérégie, the public health department has to consider population differences (ex: urban versus rural).

In order to protect our population, we believe that we need a regional portrait of the climate for vulnerable areas (ex. Longueil, Saint-Jean) and to improve the monitoring system for health indicators, following the example of the Pandemic Influenza program. The desired qualities for any HHWS system are that it is easy to apply, cost efficient and accessible to a wide variety of healthcare workers.

16. Real-time surveillance of deaths, hospitalisations, and ambulance and help-line services: What is available, how good is it, and how can it be integrated into a HHWS. *Shakoor Hajat, Francesa De'Donato, David Buckeridge*

Shakoor Hajat – London School of Hygiene and Tropical Medicine (Powerpoint)

Shakoor Hajat looked at the potential of incorporating the surveillance data collected routinely in the UK into heat health warning systems. Among the health indicators considered, calls to the National Health Service direct help-line were chosen as the best candidate. Others that were considered included mortality, which, while the most sensitive health indicator for heat-related effects, could not be collected in a timely manner in England. Hospital admissions and general practitioner consultations were considered to be poorly sensitive for heat-related morbidity and not available in real-time. Timely data was available for GP/primary care out-of-hour visits, but the sensitivity to our outcome of interest is unknown. Similarly, accident and emergency visits and ambulance calls are indicators of unknown sensitivity.

NHS Direct is a nation-wide, nurse-operated phone service for health advice, staffed 24 hours, 365 days per year where callers are given information and advice, and urgent cases may be given a referral. The caller may begin by giving symptoms, which are fed into a set of 200 different algorithms to make a clinical assessment. Data recorded are algorithms based on the topic raised by the caller, and the intervention suggested by the NHS Direct operator. The objectives of this study were to examine NHS Direct morbidity associated with high temperature, including the summer 2003 heat wave, as an indicator of morbidity in the general population, and, if possible, to identify vulnerable subgroups. To arrive at a set of algorithms that are markers for heat-related illness, the researchers used the most commonly reported symptoms of heat exhaustion and heat stroke, namely vomiting, difficulty breathing, and fever.

During the summer of 2003, a time series analysis of call rates per 100,000 showed an increase in total symptomatic calls associated with increase in temperature, while no association with heat was found for vomiting or difficulty breathing. By far, the largest group of callers were parents of young children, with people over age 65 calling least often. A small increase in fever was associated with temperature rise, and, when broken down by age group, these calls were more frequent in the over 65 and 0-4 age groups. No increase was seen in total calls during a period of extreme heat. When looking specifically at heat/sun stroke calls, a dramatic increase is seen during severe heat periods. Calls for heat- and sun-stroke are now routinely monitored as part of the UK Heat-wave plan.

In conclusion, NHS Direct data proved sensitive, but not as sensitive as mortality data. The signal for fever calls was strongest in young children as well as the elderly. There seems to be a need for a longer time-series for a significant trend to become apparent. Current options for data collection now include bulletins issued by the Q-research network, a nationally representative sample of general practitioner data that promises to do a better job capturing morbidity in the elderly.

Francesca de'Donato – Dipartimento di Epidemiologia ASL RM/E Roma (Powerpoint)

Francesca de'Donato, who is involved in both the Civil Protection and Ministry of Health national projects for the prevention of heat-health effects in Italy, described how the rapid surveillance system monitors mortality data in real-time. Unlike the U.K., in Italy mortality counts are complete within three days. Twenty three Italian cities have either operational or experimental heat health warning systems and "real time" mortality surveillance systems are activated in all of these cities during summer in order to monitor the impact of extreme temperatures on health, evaluate their performance of warning systems and assess the effectiveness of national and local prevention programs.

Demographic characteristics included in mortality surveillance comprised of gender, date of death, as well as date of registration of death, date of birth, place of birth and death, and whether the death was from a violent cause. Mortality surveillance began in 2004 and is still ongoing. Excess summer mortality during summer has been observed in many of the Italian cities, but heat-mortality graphs often show a rise in mortality in association with extreme temperatures, or with a delay of a couple of days. Having this data available without delay helps the public health and civil authorities to rapidly evaluate and modify responses.

SECTION 4
HEALTH IMPACTS OF HEAT
PART B

17. Physiology and pathology of heat exposure; the pathophysiological effects of ambient heat, and its modification by humidity, sun exposure and wind – *Michel Ducharme.* Modification of the heat response by personal behaviour (activity, hydration, clothing) – *Ken Parsons.* Physiological basis for prevention of heat stress/the impact of age, and of pre-existing heart, lung and other disease on the heat response – *Bill Keatinge.* Heat adaptation, short (over days), medium (within season), and long term – *Ken Parsons, Michel Ducharme.*

Michel Ducharme – Defence Research and Development Canada (Powerpoint)

Michel Ducharme began his talk about the pathophysiology of heat by outlining some of the basic principles of thermal regulation. Humans are affected by various physical and natural factors, from such things as temperature and precipitation to toxins and radiation. Despite being confronted by a number of stressors, we are able to constantly maintain our physiological functions including arterial pressure, biochemical functions, and, very importantly, core temperature. This is called homeostasis. Ambient heat and cold are thermal stressors which may interact with other stressors, such as wind, barometric pressure, humidity, and precipitation to increase the physiological effect of heat and cold. Humans have the capacity to regulate the rate of production and elimination of heat through physiological functions to maintain a constant internal temperature, independent from ambient temperature fluctuation. However, this comes at the price of greater energy demand, usually in the form of greater food intake.

Thermal regulation begins by sensing the environment. The sensors that allow us to do this are located both peripherally and centrally. Peripheral sensors are located in the skin, in the form of free neural endings responding to either heat or cold. Central thermal sensors are found in the hypothalamus and spinal cord, the respiratory system, in muscles and in large blood vessels.

The central control of thermoregulation is located in the hypothalamus. Here, the thermal information from the sensors is integrated and compared to a reference point. The reference point in humans is a body temperature set at approximately 37°C (36.8 – 37.6°C). A temperature difference between the thermal sensors and the reference point will induce heat production or heat loss.

There are two types of thermal responses; behavioural and physiological. The behavioural response is by far the most important. The brain-hand system is the most developed thermoregulatory system in humans, and it allows for postural adjustment, physical activity and control of the microenvironment.

When behavioural responses fail, or are insufficient, then the physiological responses come into effect. We have two types of physiological responses. The primary response is through physical mechanisms, such as heat loss adjustment through vascular control. A more physiologically costly response is through metabolic mechanisms such as shivering and sweating.

An example of a physical mechanism of heat loss to the environment is through blood flow to the skin. Experiments on forearm blood flow in response to temperature variation can involve immersing the forearm in water at 10°C and gently heating it to 45°C. The blood flow to the forearm can be demonstrated to increase dramatically from a state of minimal flow (vasoconstriction), to a state of maximal flow (vasodilatation). A large increase in blood flow brings the heat to the periphery, where it can be released to the environment. At rest in a neutral environment, about 95% of the thermal regulation of the human body is through this control of blood flow.

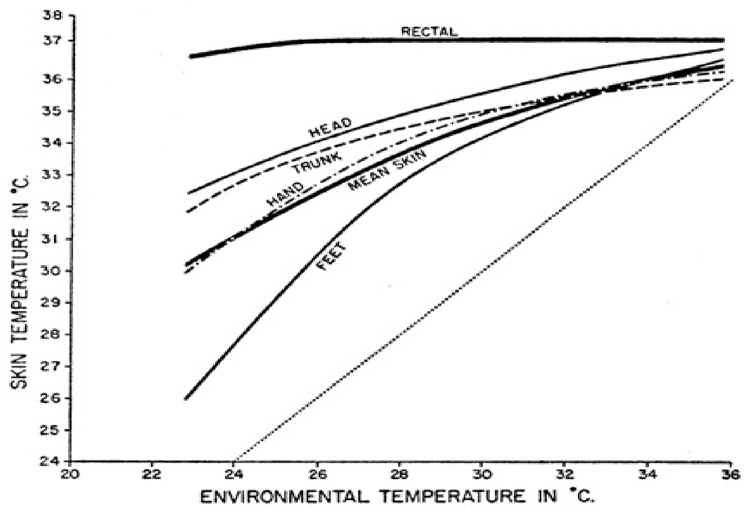


Figure 17.1 – Truncal and peripheral skin temperatures at rest, compared with core (rectal) temperature.

At thermal neutrality, a temperature gradient exists across the body, with the coldest temperatures found at the extremities. A distinction becomes apparent between a warmer core and a cooler periphery, or shell. However, as the environmental temperature increases, increasing blood flow to the skin brings all temperatures across the body towards the core temperature.

When the body is cold, the shell becomes very large, taking up most of the limbs, and the core is limited to the head and vital organs. As ambient temperature increases, the core expands and the shell retracts. In a cool environment at rest about only 5% of cardiac output goes to the shell. In a hot environment this approaches 50%. Blood flow can be increased by a factor of 40 and vascular resistance can be decreased by a factor of 5 or 6, which helps the elimination of heat. When exercise is superimposed, there is competition between the blood that goes to the skin and blood that goes to the muscles. In that situation, cardiovascular limits can be reached when the heart is no longer able to increase output, and therefore, core temperature increases. At this point, physiological mechanisms involving muscular, cardiovascular and metabolic systems come into play. During cold exposure one starts shivering, and during heat exposure one starts sweating, both of which are more physiologically expensive than adjustments of blood flow.

There are several mechanisms of heat transfer to the environment. Having brought the blood to the skin, one means to eliminate the accompanying heat by conduction, where heat is exchanged through contact between bodies. Convection heat exchange is similar, but related to fluid movement, fluid density, speed of fluid, and temperature difference. Radiation is a form of heat exchange related to emission and reception of electromagnetic waves and temperature difference between bodies. Lastly, evaporation is a form of heat exchange in which water is transformed to vapour, and is a function of partial vapour pressure. One gram of water needs 2.86kJ to evaporate. A heat storage equation can be described as follows:

S (heat storage)= **M** (heat produced as a function of metabolic rate) ± **K** (conduction) ± **C** (convection) ± **R** (radiation) ± **E** (evaporation) ± $\mathbf{E_R}$ (respiration).

Heat storage is the difference between what the body is producing at a metabolic rate and what it is losing in all avenues of heat loss. To illustrate the importance of heat exchange, using an example of a man running in a warm environment producing about 700 kilocalories per hour, about 80% of that heat loss is due to evaporation. The rest is radiation and convection. A 70 Kg man running at 7 METS (= 7 times resting metabolic rate), if losing heat only by dry means, would increase his core body temperature at a rate of 1°C every 6.5 minutes. But if that man is losing 1 litre per hour of sweat evaporating from the skin, core body temperature remains stable. Of course, depending on the temperature, that proportion will change.

At 10°C only about 20% of the heat loss is due to evaporation, but at 30°C, it becomes about 80% (Mitchell, Senay et al. 1976). The three sources of evaporative fluid loss are: 1) Insensible water loss through transepidermal diffusion which averages less than one litre per day; 2) losses through respiration are also less than one litre per day (0.3L/day); but 3) sweating can be as high as 12-15 L/day for someone working hard in a hot environment. Thus sweating can be an important source of heat loss. Sweating and vasodilatation are complimentary mechanisms that happen in conjunction. It is important to keep in mind that one can sweat and not lose heat if evaporation does not occur. The evaporation rate depends on two things: the vapour pressure gradient between the skin and the environment; and the air movement. It is important for people working in hot environments to be conscious of sweating, because it involves losing water which, if not replenished, can lead to dehydration. Sweat is composed mainly of water and some sodium chloride, so salt losses will also need to be restored.

For a comprehensive description of the thermal stressors, 8 factors identified as important are: exposure time (will affect total heat transfer); air temperature (affects conduction, radiation and convection); dew point temperature (affects evaporation); air and fluid movement (affects convection and evaporation); radiation temperature (affects radiation); and barometric pressure (affects evaporation and convection). In addition to environmental factors, one must also take into account the insulating factor of clothing because it will affect all avenues of heat loss (convection, radiation, conduction, and evaporation). Human factors, often forgotten, include not simply age and fitness but also anthropometry (surface area to mass ratio), gender, level of hydration, health status, predisposition to heat-related illness (e.g. some diseases, congenital absence of sweat glands, etc.), and personality traits (can affect perception and reaction to the environment).

The various indices of environmental stress found in the literature do not take all those factors into consideration, particularly the human factors. One of the most well known of these indices, the Wet Bulb Globe Temperature (WBGT) accounts for wet and dry bulb temperatures and radiation, but does not measure any human factors, nor does the Humidex index, a measure of temperature and relative humidity. The Physiological Heat Stress Index encompasses a limited number of indicators of physiological status, such as core temperature and heart rate. The Discomfort Index is a subjective measure of heat stress, and the Universal Thermal Climate Index (UTCI) is a modelling of physiological components and environmental components still in development. One approach, developed by Armstrong for use in athletic competitions in the United States, is a system of heat alerts indicated by varying flag colours denoting risk of environmental heat illness based on WBGT (Armstrong, Epstein et al. 1996).

The primary pathological syndromes associated with heat exposure are hyperthermia (heat stroke), dehydration, and sodium depletion. Hyperthermia occurs when the core temperature rises above the 37.7°C due to uncompensated heat gain. The tissue that is most heat sensitive is the brain, so the first symptoms observed are related to behaviour. Because of sweating one can lose up to 3.5 litres per hour while working very strenuously, and dehydration then becomes an issue. For each 1% decrease in body mass due to water loss, the body temperature and heart rate will increase by 0.3°C and 5-10 beats/min, respectively. Dehydration is classified by the following:

- *minor dehydration: 2% (1.5L)*
- *moderate dehydration: 6% (~4L)*
- *severe dehydration: 7-10% (5-10L)*
- *lethal level of dehydration: 15-20% (17-20L)*

Severe dehydration can happen within a day. Depletion of sodium (Na) occurs at a rate of 10-30 grams a day, so it takes several days of working in the heat without replenishing sodium for severe depletion to occur.

According to the International Classification of Disease (ICD), there are 15 different categories of heat illness. Heat exhaustion is the inability to continue to work due to the limitation of the cardiovascular system and is often, but not necessarily, related to water or salt depletion. It is characterized by moderate elevation of core temperature (<40.5°C), headache, dizziness, nausea, or possibly vomiting, but with normal serum enzyme levels and without central nervous system pathology. It is not life threatening, but it is the first step toward heat illness.

Heat syncope is defined as a brief fainting episode in the absence of salt and water depletion or hyperthermia, often subsequent to prolonged standing. It is characterized by blurred vision, vertigo, and nausea and is the result of pooling of the blood in the legs consequent to full vasodilatation, so blood supply to the brain is inadequate. It is found more frequently in unfit and un-acclimatized people.

Heat cramps are painful spasms of muscles, usually after exercise in the heat with large sweat losses accompanied by drinking hypotonic fluids. It results from an imbalance of electrolytes and can progress to hyponatremia (sodium deficiency characterized by a plasma sodium level less than 130 mEq/L). Heat acclimatization is not sufficient to protect from heat cramps.

The most serious heat-related illness is heatstroke. This is a life-threatening multi-system disorder reflecting collapse of the thermoregulatory system, with severe neurological symptoms. It is characterized by confusion, delirium, aggressivity, change in personality, diarrhoea, vomiting, muscle necrosis, acute renal failure, gastro-intestinal bleeding, pulmonary oedema, cardiac arrhythmia, convulsion, and coma. It is linked to hyperthermia >40.6°C, normally with dehydration of more than 7% and hot, dry skin due to decreased perfusion and sweat rate secondary to thermoregulatory system failure. Classic heatstroke develops over several days in older people with diminished cardiovascular reserve. Exertional heatstroke develops during heavy exertion in younger people.

One panellist wanted to know to what degree physicians are aware of the symptoms and standard approaches to the treatment of heatstroke. Michel Ducharme responded by saying that a growing body of literature is being published that informs clinicians how to diagnose heatstroke. Because of the frequent failure to measure core temperature when the patient arrives in hospital, it often goes unrecognized. Another panellist referred to the experimental protocols in physiology labs including only young, fit males and wanted to know if the results from these studies were generalizable to other gender and age groups. Michel Ducharme replied it is unlikely the case. The current literature aims primarily at a young and healthy population. Future experimental studies should focus more on both genders and the elderly, including populations with health problems.

Ken Parsons – Loughborough University (UK) (Powerpoint)

Developing on ideas presented in the previous talk by Michel Ducharme, Ken Parsons addressed the issue of modification of the heat response by personal behaviour. He began by presenting an acronym for how to survive in the heat: you should be Sensible, Hydrated, Acclimatized, Fit, Thin and Sober (SHAFTS). Being sensible is behaving in a way that will reduce the thermal strain according to basic physiological theories, taking into account the practical opportunities for doing so. Being well hydrated, quite obviously, means drinking a lot of fluids (acclimatization will be discussed below). People who are fit and healthy will survive heat much better, whereas the vulnerable (elderly, sick, depressed, etc.) are at greater risk. Thinness (high surface area to mass ratio) is an advantage in hot weather, as having a higher mass leads to a higher metabolic heat rate, and thus, more internal heat production. Sober (meaning no alcohol or drugs) is also an advantage as some drugs affect the thermoregulatory system directly and most substances of abuse affect the ability to judge appropriate behaviour.

Over 100 years of formal research has been conducted on standards of human response to the thermal environment, so there is ample evidence to support many of these theories. The six major factors identified that best predict how humans respond to a thermal environment are: air temperature, radiant temperature, air velocity, and humidity (which are all environmental components), and clothing and activity are important behavioural aspects. Discussing appropriate behaviours and adaptive opportunities requires incorporating all of these concepts (environmental and behavioural) to guide recommendations for avoiding unacceptable thermal strain.

To maintain a constant internal temperature within a reasonable limit around 37°C, the heat inputs must balance the heat outputs. Heat stress occurs when the heat inputs are greater that the heat outputs. The heat balance equation shows the mechanisms of heat transfer:

$$\mathbf{M - W = (C+R+E_{sk}) + (C_{res}+E_{res})}$$

Where: **M** = metabolic activity; **W** = work outputs; **C**= Convection; **R**= Radiation; $\mathbf{E_{sk}}$= Evaporation from the skin; $\mathbf{C_{res}}$= convective heat loss through breathing; $\mathbf{E_{res}}$= Evaporative heat loss through breathing.

This heat balance equation supposes that any energy produced by metabolic activity minus any work output must be balanced by heat loss or gain. This is a good principle to start with to assess and evaluate any recommendations we make in terms of appropriate behaviour.

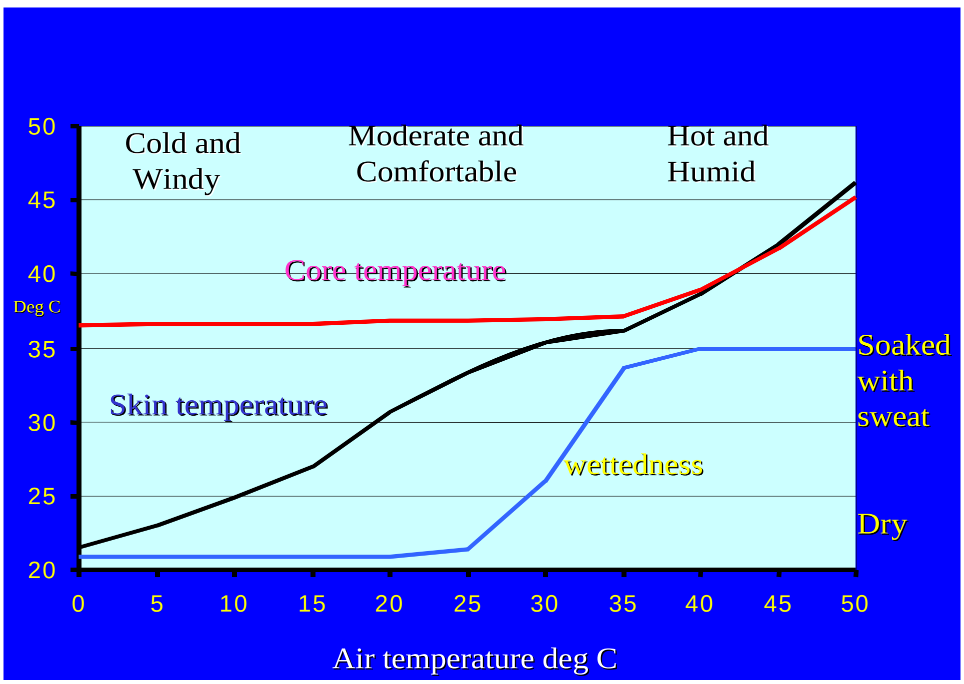


Figure 17.2 shows skin temperature, core temperature, and wettedness in relation to ambient temperatures.

The diagram (Figure 17.2) displays three principle physiological outputs: core temperature = brain and internal body temperature; skin temperature; and wettedness = skin wetness is related to the rate of sweating. The graph indicates what would happen in the heat, in a comfortable environment and in a cold environment. In the 20°C to 25°C range, individuals are not actively sweating and skin temperature will be around 33°C to 34°C. When ambient temperature rises, the wettedness starts to increase and one loses heat by evaporation. As the heat increases further, one becomes totally soaked with sweat, and the skin temperature converges with the core temperature, in fact exceeds it, so that one can no longer maintain internal body temperature. The core body temperature starts to rise and heat illness ensues.

This information can be useful to determine where heat strain starts for vulnerable people whose capacity to increase cardiac output and sweat rate may be limited. One can perform a thermal audit using the heat balance equation to determine what measures would be effective for heat transfer to the environment (e.g. blowing a fan at a person). One could then determine if, at high temperatures, you would lose more heat by evaporation than gain by convection, and it becomes possible to make a more informed decision whether to blow the fan or not.

One must not underestimate the basic risk factors for heat illness. Simple factors like inappropriate clothing can kill. High activity levels and clothing together mean people will not be able to work long without breaks and will require extra cooling facilities. Social factors, including motivation, have harmed people who have refused to slow down their activities in the heat. Poor quality health management, such as not knowing or not relaying appropriate behavioural advice, is another risk factor. Lack of opportunity or how to access the opportunity for a given environment, can be harmful. Two especially important opportunities to lessen the risk of heat-related illness are power and water. Power is needed for air conditioning, fans, and refrigeration. Water has a tremendous capacity to cool and rehydrate. Approximately 200 times more heat loss is achieved from water than from air, so sitting in a cool bath, spraying it, and putting one’s hands or feet in it is highly recommended.

Heat stress is closely related to thermal comfort, and for the vulnerable sector, the range of temperatures at which stress begins may be much lower and narrower than for the general population. To test this theory, an investigation was undertaken to find out whether people with physical disabilities would have the same thermal comfort requirements as people who have no physical disabilities, using an index of thermal comfort. There is a standard thermal comfort index, ISO 7730, which takes account of six factors: air temperature, radiant temperature, humidity, air velocity, clothing and activity. These values are then put into an equation that has been developed to predict how people would feel on a comfort scale (+3 hot, +2 warm, +1 slightly warm, 0 neutral, -1 slightly cool, -2 cool, -3 cold). The scale is used to predict how to design rooms for thermal comfort. The Predicted Mean Vote (PMV) is an index that predicts the mean value of the votes of a large group of persons on the same 7-point thermal sensation scale.

A four-year thermal comfort research program funded by the Engineering and Physical Sciences Research Council (EPSRC) was undertaken consisting of field surveys interviewing 391 people with physical disabilities and 38 carers of persons with physical disabilities. Laboratory studies were done to record the responses of 145 people with physical disabilities after placing them into warm, neutral and cool environments. A software tool was employed to integrate the results into a usable form to determine the thermal comfort requirements of people with physical disabilities**.**

The participants all wore standard clothing and the thermal chamber was set up like a living room where they watched television. After 3 hours, they gave ratings on a thermal comfort scale. The disabled subjects had cerebral palsy, spinal cord injuries, polio, multiple sclerosis, osteoarthritis, rheumatoid arthritis, hemiplegia and several other related conditions.

When comparing the disabled to the non-disabled group, the people with disabilities had a much wider range of ratings of their thermal comfort in neutral and cool environments, and their median rating tended to register slightly more discomfort in all environments.

One hypothesis to explain why the range of discomfort in the warm environment narrowed for the people with disabilities is that vulnerable people see this as a much more serious situation than do people without disabilities who recognize their adaptive opportunity to change clothing or position. So what is needed is some sort of index that takes into account adaptive opportunity, which is human behaviour. Accordingly, the Equivalent Clothing Index (I_{Equiv}) was developed to estimate the range of acceptable temperatures for both people with adaptive opportunity (i.e. without disabilities) and those without adaptive opportunity (i.e. with disabilities). On a scale from 0 (minimum) to 1 (maximum), people without disabilities scored high (0.75), and people with disabilities scored low (0.25), in terms of adaptive opportunity. In this way, a range of comfortable temperature to guide thermal conditions in offices can be calculated for both groups (people with and people without disabilities). Using standard clothing and doing sedentary office work, a comfortable range for the person without disabilities is calculated to be 20°C to 28.5 , while for the person with the lower adaptive opportunity, a narrower comfort range, 22.8°C to 25.5°C is determined.

The same approach can be used to determine a maximum temperature for offices. Using the Predicted Percentage of Dissatisfied (PPD), an index that predicts the percentage of thermally dissatisfied people, basing maximum comfort temperature on PMV = 0 and defining maximum office temperature on PMV = +2.5 (PPD 95%), one can calculate a maximum range of 33.5 to 33.9°C for people with minimal to maximal adaptive ability.

Commenting on technological developments on the horizon, Ken Parsons cautioned that « Smart » active clothing and micro-climate cooling should be evaluated using proper principles of thermal physiology. Further heat-related advice for the public included:

- ✓ “If you can't stand the heat go to a supermarket”
- ✓ Take a cool bath (fill half with normal warm water, get in, then add cold water, stay in it for at least 30 minutes),
- ✓ Spray water over yourself and sit in front of fans,
- ✓ Buy air conditioning,
- ✓ Use a buddy system.

In his closing remarks, Ken Parsons outlined some directions for future consideration. The Wet Bulb Globe Temperature (WBGT) is an internationally standardized index used in industrial setting and in marathons, and early warning systems based on it should be considered. Advice is needed from people used to living in the heat: we should consider a future conference on this subject. Research into the advice that has been given and a practical user evaluation of this advice is needed. Following this, an international standard for guidance based on sound, scientific principles should be developed.

Bill Keatinge – United Kingdom (Powerpoint)

Bill Keatinge was unable to attend the workshop, but his work on temperature, pollution, and mortality was presented by Tom Kosatsky. He illustrated some important points on the interaction on health of pollution and heat by presenting several comparisons of Finland, Britain and North Carolina (Donaldson 2003).Optimal temperatures for each climate (lowest mortality rates) were higher in warmer climates, with Britain higher than Finland, and North Carolina higher than Britain. One could also see from a 30-year time series that as the average summer temperatures increased in those 3 areas, so did the average temperature of onset of heat-related mortality, while the annual heat-related mortality per capita was reduced. This would indicate a form of adaptation of the population to the climate and to the changes in climate. Some of the difference in heat related mortality has to do with behaviours, and the way that people live with heat appears to be very different in different climates.

Dr. Keatinge questioned whether deaths in recent heat waves were due to heat or to pollution. There have been many recent claims that up to half of all deaths during heat waves are due to ozone (Fisher 2004), the concentration of which rises in hot weather. Data from his recent study (Keatinge and Donaldson 2006) show that mortality in hot weather is indeed usually higher when ozone or other pollutants are high rather than low. However, the results indicate that when ozone is high so is sunshine, which will itself increase heat related mortality. Pollution by particulate matter (PM10) or sulfur dioxide (SO_2) was not associated with sunshine, but was associated with low wind, which would also increase heat stress. Data from this same study (Keatinge and Donaldson 2006) show that ozone is also higher early in summer, when people are less acclimatized to heat, than in late summer. In a two stage Generalized Additive Model (GAM) analysis of this relationship, one sees that when one allows successively for heat acclimatization as a direct and an interactive factor with temperature, and then also for sunshine and wind, the mortalities that the analysis attributes to ozone, PM10 or SO_2 without such allowance all become non-significant.

So it does seem that heat, rather than associated air pollution, causes the great majority of deaths in heat waves. The main need is to give effective advice to the general public about how to handle high and unfamiliar levels of heat that punctuate global warming.

A point that needs to be stressed is that few of the heat wave deaths are caused by simple heat stroke, at least in temperate and cool countries. Heat stroke is essentially overheating of the body to a level that starts to denature, or cook, the body proteins. It is rare, particularly in temperate countries such as Britain. The great majority of heat wave deaths are due to other things, including coronary and cerebral thrombosis. Experiments on volunteers that we published 20 years ago offered an explanation for that (Keatinge 1986). People lose salt as well as water in sweat when they are exposed to heat. They do not make up these losses quickly. The loss of fluid raises the concentration of a series of thrombogenic components of the blood, including red cells and platelets. This in turn triggers arterial thrombosis in elderly people with atheromatous arteries.

This is not the only reason that elderly people are particularly at risk from heat stress. Apart from general impairment due to age, many elderly people suffer from cardiac insufficiency, which restricts their ability to increase skin blood flow and so heat loss under heat stress. Many also take psychoactive drugs, which can impair heat loss mechanisms either by general narcotic action or by atropine-like actions that specifically block sweating.

What general conclusions can we reach from all this? One important practical point is that you need to protect people from moderate heat stress, and not just from the severe stress that causes heat stroke. Over much of north and central Europe and other temperate regions, most heat deaths can be prevented by advising people to take measures that are a matter of course by people in southern Europe. At the beginning of summer, make sure that windows can be opened and that a fan is available. In hot weather, open windows in the early morning, and when outdoor temperature rises above indoor temperature, shut them and shade them from the sun. Avoid physical exertion at hot times of day. Keep up normal eating as well as fluid intake, to replace losses of salt and water in sweat, and start a fan. For anyone who becomes uncomfortable from heat, particularly if they are elderly or on medical drugs that suppress sweating, sprinkle water on clothing as well as starting the fan, to restore evaporative cooling. This will be effective even in air above body temperature, apart from exceptional situations where the air is fully saturated with water vapour.

For anyone showing signs of incipient heat stroke (headache, irritability, and temperature above 41°C), a cool shower or bath will provide rapid cooling. All of this is very effective, but it needs to be done straightaway. One message to be taken from the French experience in 2003 is that people should treat heat stress at home rather than wait for help from the emergency services, which were overwhelmed by calls that summer.

Air conditioning is also very effective, and is sometimes needed despite its heavy energy demands. However, acceleration of global warming by these demands can have consequences far beyond the field of health. The simpler traditional methods for keeping cool can minimize the need for of air conditioning in hot climates, and make it largely unnecessary in cool ones.

Dr. Keatinge finished with the assessment his team has made of the need for effective preventive measures in Britain during the next ten years. The fact that temperatures have risen linearly for around thirty years allows short-term assessment by simple linear extrapolation for a further ten years. Southeast England is the only region warming rapidly, and even there people are adjusting well enough to prevent any rise in mean annual heat related mortality. Cold-related mortality is falling markedly in all regions.

Overall this is good news, but a graph of this linear extrapolation shows that increased variability is causing temperatures during the hottest days and during the hottest runs of days to increase faster than mean temperatures. In southeast England the risk of a nine day heat wave at mean daily temperature of 27°C during the next ten years is around one in four. This would require effective intervention to prevent a disaster approaching that of the French heat wave of 2003.

The main message is that the direct effects of global warming on health and mortality can be largely managed by simple means and by timely advice to the public when hot weather is forecast. These will minimize the need for air conditioning, with its adverse effect on global warming.

Ken Parsons continued his presentation on heat responses by focussing on heat adaptation over short, medium and long-term periods (Powerpoint). Heat adaptation has been extensively studied, mostly using fit, young men in a military or athletic context as subjects, but certainly not using vulnerable populations. In order to better evaluate the research done in this field, we need to first define adaptation. One useful interpretation is that it represents reduced strain for a given heat load. This can be primarily achieved by behavioural responses, but there is some physiological adaptation to heat, as well. Questions that Ken Parsons has sought to focus on include:

Do people from hot climates adapt and hence have an advantage?
Is it just about behaviour, or are there physiological advantages?
Are people from hot climates acclimatized to heat?
Can people from temperate or cold climates acquire physiological adaptation?
What would adaptation look like in terms of physiological response?
Can we maintain core temperature, and thus, minimize strain?

From a purely physiological standpoint, to reduce core temperature in the face of elevated ambient temperatures, one might look at ways to influence parameters previously seen in Figure 17.2. Changing certain factors such as skin temperature and wettedness (more and earlier sweating) would be very useful, as would increasing the versatility of the vasodilatation and vasoconstriction system (e.g. increase blood volume so there is more blood to cool down the core); and also decreasing salt secretion. When investigating adaptation of research subjects exposed to heat, these hypotheses were not far from actual observations.

When people are acclimated in the laboratory, they are put into the thermal chamber at very hot temperatures (40˚C – 45˚C), and are required to exercise strenuously. They start sweating early and keep sweating for long periods. This protocol is repeated daily for 10 days, so people with disabilities or illnesses would not be able to endure this regime. Measurements are taken of indicators of thermoregulatory responses that would signify the occurrence of acclimatization, such as increased blood flow, earlier and more even sweating, reduced heart rate, reduced core temperature, and reduced salt secretion in sweat.

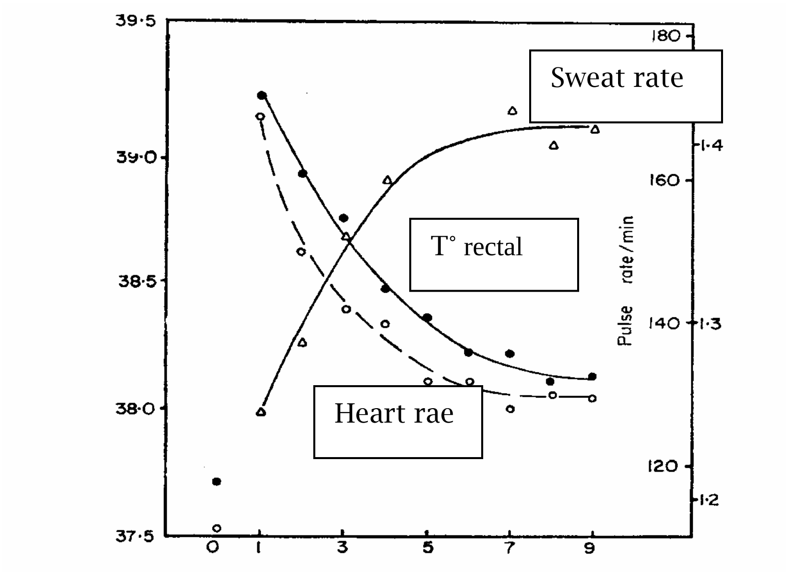


Figure 17.3 – Subjects exercising in a thermal chamber at 48.9˚C (dry bulb temperature), 26.7˚C (wet bulb temperature). Sweat loss in litres (kg/70 kg/hour), heat rate and rectal temperature are illustrated. Time scale below is measured in days (Lind and Bass 1963).

A classic diagram from a 1963 study by Lind and Bass is shown above. Subjects were exposed to a hot, dry climate where they worked in the heat for 10 days. They started the study with very elevated rectal temperatures, low sweat rates, and fast heart rates, but were observed to have a reduction in all these heat strain parameters after 3 days, with further acclimatization over the remaining 10-day period.

Results from a large research program done in cooperation with the British military using 18 study subjects exercising in heat showed that all individuals increased, and many even doubled, their sweat rate over the 5-day period (MacPherson, Adam et al. 1960). A similar study shows that Indian soldiers brought to England lost acclimatization working in the cold, but regained it when re-exposed to heat (MacPherson, Adam et al. 1960). In another study, it was found that the sweat rate was increased by merely increasing the body temperature without exercise using subjects wearing impermeable suits in the heat. One 1973 study on the sweat rate of Israeli villagers using subjects who were not necessarily physically fit, demonstrated an increase in sweat rate during the summer (Fox, Even-Paz et al. 1973). In an experiment using self-controls, one arm of each subject was kept cool while the rest of the body acclimatized to heat, and results showed that the unacclimatized arm did not change its sweat rate. The conclusion that can be drawn from these studies is that acclimatization has to do with training of the sweat glands.

With respect to thermal comfort, a number of experiments were done to determine the effects of acclimatization on thermal comfort. One study looking at the effects of gender found no gender differences in warm and neutral environments, but at cool temperatures (18.5°C) females felt distinctly cooler, perhaps because of the size of their extremities. In an effort to discover if acclimatized subjects had a different range of thermal comfort, six male subjects' comfort responses were recorded before and after acclimatization. No significant difference was found after the acclimatization to either a neutral (23°C) environment or a slightly warm environment (29°C).

Some conclusions that can be drawn from this body of research suggests that all people seem to be able to acclimatize to heat, however there is little research on how vulnerable people adapt to heat. Furthermore, people who live in the heat seem to be acclimatized to it, but further research is needed. There seems to be some evidence that those exposed to heat before a severe heat wave will have improved chances of survival, however, the mechanisms for this are still uncertain. It is clear that people learn appropriate behaviours for the heat but it is not clear that there are significant physiological changes. Acclimatization to heat does not affect conditions for comfort. The evidence suggests that people will adapt to heat, particularly through acclimatization but it is not clear that this occurs in the type of populations of interest to public health during heat waves. Since it takes 3 or more days to acclimatize significantly, this is not sufficient time for one to acclimatize during a heat wave.

Questions from the panel were directed to all three speakers and included a query by Larry Robinson who wanted to know what the impact of heat is on metabolic processes. Both Ken Parsons and Michel Ducharme responded that the effect of heat on metabolic rate can be described by the Q-10 relationship, which is a doubling of the rate of biochemical reaction every 10˚C increase in internal temperature. Enzyme catalyzed reactions speed up, but the enzymes do not stop working until critical temperatures are reached, at which point severe heat illness is triggered.

Glenn McGregor commented that if we disregard unusual heat wave events like 2003, the normal maximum duration of heat wave events is about 3 or 4 days, so the opportunity for natural acclimatization through the standard heat wave duration is not available. Ken Parsons agreed that the major effects of acclimatization are observed in the laboratory only after the first 3 or 4 days, and continue over 10 days. However, the intensive training done in experimental conditions is not the same as what normal people would do in their homes. To say that without an active attempt to acclimatize, the opportunity to acclimatize in a normal heat wave is not there may be a little cautious because there may be a small amount of ability to get accustomed to the heat. A little sweat in a vulnerable person (age 80 – 90) may give a great advantage, but we do not really know.

Jason Samenow brought up the issue as to what advice we should give about using fans – are there any circumstances under which one should not recommend using a fan? The advice his group is giving is not to use a fan in an enclosed room when the temperature is over 90 ^{O}F. Ken Parsons replied that he would not recommend giving this advice. He would advise the public to use the fan with two caveats – if there is 100% humidity, it may be ineffective or counterproductive, and also the fan itself produces heat, so one would have to be careful that the fan is not producing too much heat. However, evaporating water from the face is a good thing to do. Bill Keatinge would recommend fan use even above 98.4^{O}F, much higher than the EPA cutoff of 90 ^{O}F. Ken Parsons recommends that it can even be used up to 100^{O}F.

Larry Robinson countered this by saying that his agency did a lot of research into this issue, and that this advice may be suitable under normal conditions. However, the issue of dehydration is significant, particularly among the elderly who are usually dehydrated. Putting them in front of a fan increases the perspiration and evaporation, which increases their dehydration. Many times in his jurisdiction, individuals are found sitting in front of a fan at the time of their death. Larry Robinson contends that the fan dehydrated them and caused their death. Ken Parsons suggested that to blow air across someone who is slightly moist is a more efficient way to cool down, that is, to spray them in front of a fan. He added that there may be a need to investigate this contention, because he is not 100% sure that these people would have died through dehydration. He added that another precaution to keep in mind is to drink and stay hydrated.

Michel Ducharme remarked that his group did a comparison of using fans with spray compared to immersing the hand in cold water (17˚C), and found immersion to be more effective. Another advantage is that one does not need special equipment.

Monica Campbell expressed a concern that more and more people in southern Ontario, and certainly Toronto, are using air conditioning. They may not be very physically active and are probably quite sedentary. Are they allowing their bodies to acclimatize to the heat living in such an artificial severely air conditioned environment? What is the policy direction that we want to get out? One of the things we would like, to better protect the environment, is that people not set their AC so low. Have there been any studies examining people living in these artificial environments, and are they robbing their bodies of the chance to acclimatize?

Ken Parsons replied that he thinks that would be true. People who live in a cooler climate will not acclimatize to heat without active effort. In an extremely hot climate, like Singapore, which is on the equator, most people are living in cold, air conditioned environments. One does not necessarily find that the people are naturally acclimatized to the heat. However, he believes we need to consider this further because he does not want to go against the AC when the heat comes along. We should leave global warming until we’ve saved the lives of the vulnerable people during extreme heat events. The US and Canada have led in this. One needs air conditioning; it’s a good solution.

Glenn McGregor added that the idea of adaptive opportunity is appealing, but one’s ability to avail oneself of this is a practical problem. He asked the speakers if either of them could comment on the practicality, feasibility, or utility of the Universal Thermal Comfort Index, given that response to stress varies within and between populations?

Ken Parsons responded that he has not been fully involved with the UTCI, but he is involved with the ISO standardization. He added that the WGBT index is a good practical index and it has facial validity, although it is affected by factors that are important. To overcome this, one then needs to get the value and then interpret it in terms of human factors. The WGBT is used widely in industry and now it’s used as part of a warning system in fun runs. He has written a paper on its application as a simple index one can use globally (Parsons, 2006). The Japanese are thinking of using it as an index for their warning system, and currently, there’s some modeling going on. It is a little bit different from the weather station info, so there are issues related to delivering that information and measuring it.

Christina Koppe also said that she had not been directly involved with the UTCI, but she responded that there are plans to develop a very complicated model of the human body, which may be too detailed for a universal use. She stated that the model is quite good for applications when one needs to model an individual, but for populations there are some limitations.

Glenn McGregor added that the validation of the UTCI is the predicted mean vote, which is developed for mid-latitude whites (Europeans essentially). If one takes that somewhere else in the world, then the threshold range is shifted considerably.

SECTION 5

PRACTICE OF HHWS

18. Taxonomy of HHWS: Physiologically-based (German Weather Service), derived from the epidemiology of heat overload (ICARO—Portugal), Bayesian approaches (France), synoptic categorisation (with optional techniques – University of Delaware). *Christina Koppe (overview of European systems plus Germany), Mathilde Pascal, Scott Sheridan.*

Christina Koppe – Deutscher Wetterdienst (Powerpoint)

The ÍCARO project was developed subsequent to extreme heat episodes in 1981 and 1991, and a heat health warning system has been implemented based on this model since 1999. An ÍCARO index was developed to predict heat-related mortality using a historical 20-year time series data in a multiple linear regression model analyzing the relation between heat and mortality calibrated for the district of Lisbon.

When a heat wave is predicted (defined by means of a temperature threshold of 32°C combined with a minimum duration of 2 days), a simplified statistical model is used by the surveillance system to calculate the expected heat related mortality. One part of this algorithm is the so-called accumulated thermal overcharge (ATO) over the threshold 32°C until the day for which the calculation is made. The variable accumulated thermal overcharge can be generalized for any level of temperature τ:

$$\underline{\mathbf{ATO_t(\tau) = \mathit{HLen_t}(\tau) \times Exct(\tau)_t}}$$

Where:

$$\boldsymbol{\mathit{HLen_t}(\tau) = \begin{cases} \mathit{Hlen_{t-1}}(\tau) + 1 & \mathit{if}\ \ Tmax_t \geq \tau \\ 0 & \mathit{if}\ \ Tmax_t < \tau \end{cases}}$$

is the number of consecutive days that the maximum air temperature (Tmax) is above τ until day t, and:

$$\boldsymbol{Exc_t(C)_t = \begin{cases} Tmax_t - \tau & \mathit{if}\ \ Tmax_t > \tau \\ 0 & \mathit{if}\ \ Tmax_t \leq \tau \end{cases}}$$

is the excess of the maximum temperature above τ on day t.

Based on an indicator for the time of year and daily maximum predicted temperature, along with an ATO variable, an index is derived which can trigger a set of interventions.

The ÍCARO index is calculated as follows:

$$\underline{\textbf{ÍCARO Index} = \mathbf{(M_{eh} \div M_e) - 1}}$$

Where $\mathbf{M_{eh}}$ is the number of expected deaths with the effect of heat, and $\mathbf{M_e}$ is the baseline summer mortality.

Colour coded ÍCARO levels are: **1** (green) I < -0.31 "no hazardous weather conditions foreseen and no interventions taken"; **2** (yellow) -0.31 < I < 0.31 "Weather sensitive activities may be affected. Pay attention to the development of weather conditions" and no special interventions are undertaken; **3** (orange) 0.31< I < 0.93 "Probable effect on mortality. Weather conditions involving moderate to high risk. Keep informed of their development and follow advice of civil protection authorities" and an intervention in the form of an announcement is made that a heat wave may arrive within the next few days; and **4** (red) I > 0.93 "Heat-wave alert: Very probable effect on mortality. Weather conditions involving high risk" and intervention measures are triggered within the Portuguese General Health Directorate and the Portuguese Civil Protection Service, e.g. the public health emergency line is used as a heat line and is reinforced with nursing personnel.

Since its implementation, it has performed well and accurately predicted the health effects. However, modifications were made after the 2003 European heat wave to capture the changing effects of acclimatization over the summer, and a dynamic threshold was substituted for the fixed threshold of 32°C.

Christina Koppe – Deutscher Wetterdienst (Powerpoint)

Christina presented a look at the German physiologically-based heat health warning system. This system is based on a physiological indicator, the Perceived Temperature (PT). A conceptual model for acclimatisation is then added. Perceived temperature is modelled on human thermoregulation by means of heat production balanced with different mechanisms of heat exchange with the environment, summarized in the heat budget equation:

$$\mathbf{M+W+Q^{*}+Q_{H}+Q_{L}+Q_{Sw}+\ Q_{Sw} = \Delta S.}$$

where **M** is the heat produced by metabolic processes, **W** is heat lost through work, **Q*** represents radiant heat flux (heat is released through blood flow to the skin), $\mathbf{Q_H}$ represents convective heat fluxes (affected by wind speed and air temperature), $\mathbf{Q_L}$ and $\mathbf{Q_{Sw}}$ represent evapotranspiration (through blood flow to the skin and secretion of sweat), and $\mathbf{Q_{Sw}}$ represents heat exchange via respiration (influenced by humidity and air temperature). $\Delta\mathbf{S}$ represents a change in heat storage. Conduction is not used in this context because it only minimally affects heat exchange.

After a short period of exposure to heat, the physiological mechanisms of heat exchange, especially heat release, become more effective. This process of acclimatisation to heat varies between seasons and populations and is the reason that health effects depend on the time of the year and the climatic region. Note that there is a difference between adaptation and acclimatisation. Acclimatisation refers to physiological changes in the body, while adaptation concerns both the physical and behavioural elements. Only short-term acclimatization and behavioural adaptation are addressed in the model.

Many indices are used for assessing the thermal environment and for setting thresholds at which heat becomes oppressive for human health. The goal for the German HHWS was to develop a procedure which enables a health relevant assessment of the thermal environment, taking short-term adaptation into account. A standard procedure called Perceived Temperature (PT) was already being used in the German Weather Service. PT is a heat index based on the heat budget model (Fanger 1972; Gagge, Fobelets et al. 1986) and is defined as the temperature of a reference environment in which the perception of heat or cold would be the same as under the actual weather conditions (Jendritzky 1979; Jedrinzky 2000 ; Jendritzky, Bucher et al. 2000). The assessment is made for a standard male with a standard metabolic rate that corresponds to walking outdoors.

The model developed is called HeRATE (Health Related Assessment of the Thermal Environment). It comprises an absolute function that includes absolute limits due to the constraint of keeping core temperature constant at 37°C, and a relative function due to short-term adaptation (acclimatisation plus behavioural adaptation).

For the absolute function, the recommendations of the Association of German Engineers (VDI) were used, which categorize thermal loads for PT thresholds (VDI 1998; Friedrich 2001; Jendritzky, Maarouf et al. 2001). There is a large comfort range between 0°C and 20°C outdoor temperature, because one can easily adapt one's clothes to reach a comfortable level. The VDI recommendations have 9 different categories of heat stress (-4 to -1: cold stress, 0: neutral, +1 to +4: heat stress). The degree range for cold stress is larger than heat stress (13°C vs. 6°C) because in the cold, one can put on more clothes, whereas in heat one can only take off so much.

Increment (K)	**PT (°C)**	**Thermal load category**	
	≤ -39	-4	extreme cold stress
13 -[	-39 to -26	-3	strong cold stress
13 -[	-26 to -13	-2	Moderate cold stress
13 -[	-13 to 0	-1	slight cold stress
	0 to 20	0	thermal comfort
6 -[	20 to 26	1	slight heat load
6 -[	26 to 32	2	Moderate heat load
6 -[	32 to 38	3	strong heat load
	≥ 38	4	extreme heat load

Table 18.1 – Thermal load categories and temperature ranges.

Based on a literature review, the upper and lower parts of the comfort range were modified using the relative function. An empirical model of behavioural adaptation shows an almost exponential curve in capacity to endure heat from the last 10 days to the most recent day (Morgan and Dear 2003). The greatest amount of acclimatisation occurs in the last three to five days and tails off beyond 10 days. A conceptual model was developed using these ideas for filter weights for PT for the last 30 days ranging from almost zero 30 days ago increasing to 0.06 for the most recent day. When these weights are applied, it causes a time lag in the PT curve and smoothes it. The absolute and the relative Perceived Temperatures (weighted for adaptation) are combined as two thirds and one third, respectively.

Thirty years of mortality data from southwest Germany was examined for the effect of different thermal load categories on relative mortality. There was a significant increase in relative mortality in both the cold and the hot extremes, with the minimum relative mortality observed in the comfort range (category 0). Data from other European cities (London, Lisbon, the Netherlands, Madrid, and Budapest) measuring the effect of thermal heat load categories on mortality showed roughly the same pattern. The minimum relative mortality for Lisbon and Madrid were observed in the slight heat load category (category 1). Reasons for this could be either long-term adaptation, not included in our model, or urban bias because the radiant temperature and wind speed are based on data collected from airport weather stations, not in urban areas, which may offer more shade from buildings. Based on this historical data, a significant mortality increase (>10%) is seen on days with a strong heat load (+3), so a warning is issued at this threshold.

Using the weather forecast for the next 3 days, the results from a local weather model developed on a 7km x 7km grid are transmitted to meteorologists responsible for the forecast for single stations (data points). Based on input parameters (cloud cover, wind speed, dew point temperature, air temperature), the Perceived Temperature is then calculated for every hour using the HeRATE procedure and these PT values are then regionalized to the county scale (415 districts in Germany) for noon (slightly below the maximum temperature) along with a rolling two day mean to account for a duration effect. If this is above the threshold, the meteorologist then issues advisories for "warning districts", which can be several counties with similar climates (counties are aggregated into 40 warning districts). Also included is a vertical component of up to 600 metres for higher altitudes.

The advantages of this system are that it can be applied to different regions with different climate characteristics; it has area-wide application; it is independent of the time of year; it can be used for such things as climate change assessment as well as heat warnings; it can be used for smaller populations; and mortality data is not compulsory. Some of the problems associated with the system are that long-term adaptation has not been taken into account; it uses only a conceptual model for short-term acclimatisation and adaptation; an acclimatisation regime for heat is used also for cold stress; there has been no verification until now; it may have lower accuracy than some one or two parameter models due to the difficulty in forecasting such things as cloud cover, etc. which are used by the PT model; and an upper threshold for long heat periods is probably needed. Also no real formal feedback from the health system yet has been received, thus far.

Mathilde Pascal – Institut de Veille Sanitaire, département santé environnement (Powerpoint)

In 2003, a Heat Watch Warning System was developed in France to anticipate heat waves that may result in a large excess of mortality. According to its mandate as given by the Ministry of Health, the system had to be nation-wide and operated by the Institut de Veille Sanitaire working with Météo-France. This system was to be used to activate a national action plan which was developed by the Ministry of Health. With only five months to develop the system and with no additional human or financial resources it was decided to make it very simple and quick. The system was developed on the basis of a retrospective analysis of mortality and meteorological data in 14 pilot cities. The primary developmental tools of the system are an analysis of forecast biometeorological indicators, integration of qualitative information to guide judgment, and an analysis of real-time mortality and morbidity data. Pilot cities included Bordeaux, Dijon, Grenoble, Le Havre, Lille, Lyon, Marseille, Nice, Paris, Poitiers, Rennes, Strasbourg, Nantes and Toulouse.

After a review of the literature, several meteorological descriptors were tested in relation to levels of excess mortality. Daily observed meteorological data was collected from 1973 to the year 2003. This included Tmax, Tmin, Tmean, dew point temperature, and thermo-hygrometric index (a simple index based on maximum daily temperature and relative humidity -THI). Daily indicators for these parameters were tested as well as averaged values over the last three days and lag 1, 2 , and 3 days. Daily all-age mortality was collected from this period as well as that of over 65 years and over 75 years. For a health indicator, daily mortality, summed last 3-day mortality (to account for duration and to smooth the inherently variable data), and mortality lag 1, 2, or 3 days were used. These indicators were studied for various meteorological thresholds and in relation to different levels of daily mortality, corresponding to an excess of 10, 20, 50 and 100%. The aim was to determine the best indicator for detecting an excess mortality defined as the sanitary threshold. Since the interest was in a major heat-related epidemic event, the mortality threshold was set on greater that 50% for major cities, such as Paris, Lyon, and Marseille, and 100% excess mortality for smaller cities.

A sensitivity (probability to be above the meteorological threshold when the excess mortality is above the sanitary threshold), a specificity (probability to be below the meteorological threshold when the excess mortality is below the sanitary threshold), a positive predictive value (PPV: probability to be above the sanitary threshold when the meteorological threshold is overtaken) and a negative predictive value (NPV: probability to be below the sanitary threshold when the meteorological threshold is not reached) were defined. A Receiver Operator Characteristic (ROC) curve was plotted (see figure 18.1) to visualize the sensitivity (Se) and the specificity (Sp) of the system. Finally, the Tmin and Tmax were selected as the best indicators for most of the cities, which are, fortunately indicators that are quite easy to predict with a certain level of confidence.

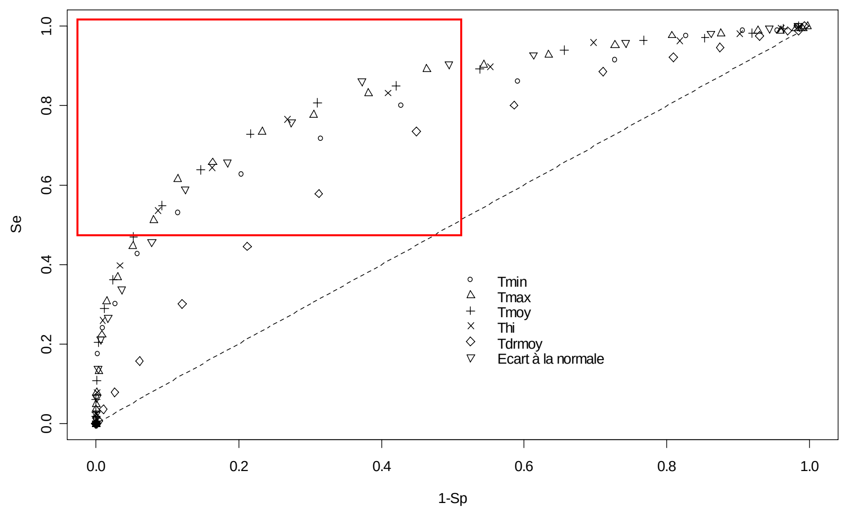


Figure 18.1 Receiver operator curve for Paris used to visualize the sensitivity (Se) and the specificity (Sp) of the system.

Next, after discussion with the stakeholders, the thresholds for each pilot city were chosen as a balance between sensitivity and specificity. Simulations were done with forecast data, and the Paris model showed very good results.

After choosing the best indicator and the appropriate thresholds in the 14 pilot cities of our study, the system was extended to 96 cities to cover the whole French metropolitan territory using percentiles of the meteorological indicators. Se, Sp and PPV were calculated using the 94th to 99th percentiles for 50% and 100% excess mortality. The percentiles that gave the best sensitivity and specificity for the pilot cities were then used to compute the thresholds of the cities that were to be included in the HHWS. The best percentile (specificity, sensitivity) was 99.5.

A key limitation of an approach based on excess mortality is its application to cities with low levels of daily mortality. Further, this system cannot identify a 10% increase in mortality because it does not allow the detection of small events. The warning thresholds were chosen to prevent large epidemic events linked with extreme temperatures. It is probable that the sanitary threshold could have been lower using stronger statistical methods to establish the relationship between meteorological data and mortality. For instance, systematic removal of accidental deaths that are interfering with the relationship would improve the reliability of the computations. Air temperature was chosen to describe the heat load, but several other parameters, including cloud cover, consecutive days of hot weather, and wind speed are also to be considered.

The system was evaluated by an independent consultant who concluded that the system was efficient to detect potential harmful heat related events and that there was very fruitful collaboration with Météo-France. Further improvements suggested by the consultant were to refine the internal organization.

Scott Sheridan – Kent State University, Dept of Geography (Powerpoint)

The development and implementation of the synoptic heat-watch warning system were described by Scott Sheridan. The synoptic methodology examines weather holistically, not by individual variables, and categorizes weather data into one or several different weather types, or air masses, designated Spatial Synoptic Classifications (SSC). The health response to these air masses can then be assessed. This holistic approach differs from other systems based on physiological models that use historical mortality data to confirm their thresholds, or systems that look at individual weather parameters associated with a mortality response. While all of these models relate health to weather, their theoretical constructs differ.

Synoptic methods were developed using data from several pilot cities (Sheridan and Kalkstein 2004). For these initial cities, up to 24 years of mortality data was obtained to identify which weather conditions are associated with statistically significant rises in mortality. The mortality data is processed and standardized to account for changes within a season as well as changes over time, e.g. through demographic change, to arrive at a value for anomalous mortality as well as a baseline value. The main objective is to minimize Type I and Type II statistical errors that would result in calling too many or too few warnings.

The SSC uses many weather-related variables: temperature at 4 different times of the day (at 3, 9, 15, and 21 GMT) to account for not only maximum temperature, but also overnight temperature, dew point depression, ranges in temperature and dew point for the day, pressure, and cloud cover, some of which have lesser impact but are still very important, especially, for example, when relating cloud cover to the heat load on a building. These data are used to classify each day into one of eight different air mass types:

- DP (Dry Polar)
- DM (Dry Moderate)
- **DT (Dry Tropical)**
- MP (Moist Polar)
- MM (Moist Moderate)
- MT (Moist Tropical)
- **MT+ (Moist Tropical Plus)**
- TR (Transition)

The two main offensive air masses are Dry Tropical (DT) and Moist Tropical Plus (MT+). These are the two hottest air masses and are most significantly associated with higher mortality. In both DT and MT+, the apparent temperature or Humidex values tend to be somewhat similar despite DT having higher temperatures and MT+ having higher dew points. As DT days tend to be sunnier than MT+ days, mean ozone levels are higher on these days as well (Sheridan and Kalkstein 2004a). As a result, one can use the presence of this air mass to approximate ozone and particulate pollution levels.

The SSC system is available for 330 cities throughout the U.S. and Canada, along with some limited networks across Europe and individual cities elsewhere. The weather types vary from place to place, for example, the DT conditions in Montreal would involve temperature values much lower than in Phoenix. They also vary over the course of the year; in Rome, DT in July is going to be hotter than DT in May. Thus, seasonality as well as spatial variability is accounted for.

In the statistical relationships, all-cause mortality data are utilized, since the relationships do not change greatly when traumatic mortality increases are excluded, as they tend to be a small percentage of the total mortality. Also, since crime rates go up in hot weather, weather may be an element of causality for traumatic deaths, though this remains uncertain. From these data, air masses are determined to be "offensive" based on their mean response, that is, whether they are associated with statistically significant increases in mortality. The mortality thresholds are a lot lower in magnitude than those which drive the system in France – generally with statistical significance of 10% or less increase in mortality.

Frequently, these "offensive" air masses not only have increases in mortality, but also have increases in variability. For example, Shanghai has a rate of anomalous mortality of 12.5% under MT+ conditions, while Rome shows anomalous mortality for both DT and MT+ air masses at 7% and 4.3%, respectively. One can use absolute regression or statistical responses to determine if mortality is greater than expected and by how much, or one can use a binary response – is mortality greater than expected, how often does that happen? Excluding extreme heat waves like Chicago in 1995 and Europe 2003, even on the most "offensive" day, looking into the historical record, there still is a good chance that daily mortality will be below normal simply due to random variation.

Using a probability distribution for all air masses in Toronto, for the two "offensive" air masses (DT and MT+) there is only a 60-65% chance that increased mortality will be seen on those days. Yet the dry polar air mass, associated with comfortable conditions, bears an almost 40% chance of excess mortality. Within air masses, a lot of variability is evident. In Rome, MT+ with hot and humid conditions is very offensive up until mid-July, then mortality actually goes below normal towards the end of their summer. The algorithms developed are location and air mass specific; they predict actual excess mortality or likelihood of excess mortality depending on the city. The overall R^2 values are rather poor, but if one predicts mortality only within the "offensive" air masses, the R^2 values go up very significantly, some as high as 0.4 and 0.5.

The system is web-based with different levels of thresholds. The highest alert level in the U.S. is called Excessive Heat Warning, while in Toronto it is termed an Extreme Heat Advisory. There are also temporal parameters where an excessive heat watch is projected a day or two in advance and an Excessive Heat Outlook is available for some cities for up to five days. There is considerable variability, but on average about seven or eight warnings per year are issued in most cities.

The system is run as automatically as possible. There is an initial morning run (usually ~0300 local time), and an afternoon run (usually ~1500 local time). Data are needed for every six hours, and if the forecaster updates the forecast, the advisory system will automatically run with the updated data. The output is password protected so that the public cannot access it. Every stakeholder who has a vested interest has access to it (health authorities, local weather office, etc.). Depending on the city, different groups look at the website and may or may not communicate with each other.

Challenges with implementing the system are found in areas that have weak heat-health relationships, smaller locations; and hotter locations where the rise in mortality is significant but the percentage isn't as big (5-7% instead of 10-15%). Sometimes there are heat warning forecasts that aren't coherent from one entity to the next. These patchwork patterns likely come about because criteria are not very well developed. Effort is placed on making the algorithms spatially cohesive. Borderline situations are difficult, as on these days a relatively minor forecast change can alter the result. The system output, thus, is only a recommendation and the local health authority has the final say. One final point to keep in mind: when collecting data for verification, it is necessary to have long data sets because the natural variability in mean response to apparent temperature overwhelms the trends in the short-term.

Questions from the panel included one from Mathilde Pascal, who wanted to know what the minimum size of a population needs to be for this system to be used. Scott Sheridan responded that the smallest metropolitan area for which this system has been developed is around 500,000 people. However, he has worked with mortality data in counties with 5000 people. Mortality data can be thought of as a continuous distribution when one has a large population, but it becomes very discrete in a smaller population, and therefore problematic. One needs a higher threshold in cities that have 1 death per day.

19. Countries/cities' experience with HHWS – *Larry Robinson, Norman King, Françoise Bénichou, Anton Haffer*

Lawrence Robinson – Philadelphia Department of Public Health

Dr Robinson described Philadelphia's experience with the development of a Heat Health Warning System, the first such system in the country. It started with the Philadelphia Medical Examiner, Dr. Mirchandani, who noticed there were more bodies in the morgue during high heat periods. He was able to classify hundreds of these deaths as heat-related, whereas other larger cities were reporting only 2 or 3 heat-related deaths. This prompted much speculation from the health community, and as a result, the CDC came to Philadelphia and did an analysis whereby they compared baseline mortality during the same time of year with heat wave mortality, and the adjusted analysis showed an excess mortality that could only be explained by the heat. This proved that heat was the greatest of all natural disasters in the region, killing more people than earthquakes, hurricanes, and floods. As a result, city administrators consulted with Dr. Kalkstein and a heat warning system was developed based on historical data. Using this historical data, one could predict the excess mortality based on offensive air mass-mortality functions.

The effectiveness of the program hinges on the interventions to mitigate the adverse health effects of heat waves. Government funding for these measures was unavailable, so a group was put together called the Philadelphia Heat Task Force, made up of groups concerned with the elderly, civic groups, tenants' rights groups, and city services. Existing resources are used as much as possible for the program, which is crucial, because money targeted to a specific program is not always protected. One of the program's biggest supporters is the Philadelphia Corporation for Aging, which is funded by lottery money. They had an existing senior help line, which, during the summer, becomes the heat-info line, manned by nurses from the health department. This became the starting point for the program's operations. Outreach teams made up of sanitarians (who inspected restaurants) and nurses from the health centres visit shut-ins, because surveys identified the isolated elderly as the city's most vulnerable population. A buddy system is another critical intervention element. In Philadelphia, a block captain's group was set up to do street work, and during the summer, they are used as an outreach system. There are more than 8000 block captains and they are sent a mailing each year to encourage them to check up on the elderly residents on their block. The system becomes complex when the utility companies and others are involved, but the central tenet remains making use of already existing structures and turning them toward the heat program. The modifications to the system have involved allowing it to become more automatic now that the infrastructure is in place, needing less guiding input.

Norman King – Direction de santé publique de Montréal (Powerpoint)

Norman King added several comments based on the Montreal heat health warning system experience. Firstly, when there is a boundary situation and conditions are just at, but do not fully meet warning or alert criteria, this becomes a very complex situation. It requires a lot of communication among partners to decide how to proceed. Secondly, it is essential that all necessary preparations are done before the alert situation is reached. An intense information program starts in May and goes through the whole summer, so if preparatory aspects of the program are very efficient, when alert criteria are met, the work is largely already done. Thirdly, in terms of using existing resources, a very key point, in Montreal full advantage is taken of existing structures such as Info-Santé, a health info line, and a very well organized community health structure which is also used to deal with heat alert situations. A guide was developed on a regional basis and distributed to the 12 local health centres to assist them to create a local health plan using existing resources. Not only do they deal with people in their homes, they also deal with the nursing centres and private residences, so by using the existing resources, the HHWS can benefit a great deal.

Françoise Bénichou – Météo-France (Powerpoint)

Françoise Bénichou stressed the need for communication in the French Heat Health warning system. Among the critical communication goals of the system is speedy delivery of information that is easy to understand and use. Météo-France aims to provide coherent and consistent answers for the authorities in charge of civil security facing many phenomena related to severe conditions, and to give them the means to anticipate and to prepare for and manage a crisis. On a more general level, they seek to inform the population through the media and give behavioural advice adapted to the situation. The heat warning system operates on a four-tiered scale, the top 2 levels, red and orange, correspond to *particularly dangerous and intense meteorological phenomena* and *potentially dangerous and unusual meteorological phenomena,* respectively. When these levels are reached, Météo-France electronically contacts all authorities responsible for safety (ministry, civil protection services, firemen, etc.), health departments, health professionals, and French media agencies by issuing a chart showing affected areas and giving behavioural advice. In case of red alert, radio and some additional media are contacted. Surveys reveal that 74% of the French population know the vigilance procedure, largely thanks to television, and during that last summer's heat wave the behaviour of the population changed markedly.

Météo-France faces pressures from the media, government and health services because, after the extensive heat-related mortality following the 2003 heat wave, they are afraid of not activating a warning early enough. The health service, the Institut de Veille Sanitaire (InVS), had difficulties taking into account forecast uncertainty, and tended to trigger warnings as soon as the thresholds were reached. After running for 2 years, the system is better, thanks to experience. Another difficulty is organization, because there is a very short time between producing the data and InVS getting the data. The national météo service is in contact with InVS, but it is difficult when there is a widespread heat wave to have in-depth discussions with each French department.

Anton Haffer – USA NWS Arizona State Liaison & Forecast Office

Anton Haffer, a Phoenix-based meteorologist from the U.S. National Weather Service shared his experience creating a heat health warning system. Located in the American southwest, Phoenix has unique climate issues. Heat is considered a given, so it is difficult convincing people that there is a heat problem. For the first three years the system implementation consisted of meteorologists issuing warnings based on meteorology and the health community responded when appropriate. In 2005 there was a heat wave that made headlines internationally, so the health community became more involved.

Another distinctive problem is that in the first part of the summer there is a traditional dry heat, but in the second part of the summer moisture arrives from the monsoon and humidity becomes an issue. In desert climates there are 2 types of air conditioning; the refrigerated type that most people are familiar with, but in the desert southwest a more rudimentary form (called a swamp cooler) based on evaporative cooling is used by the people in lower socioeconomic classes. The hot, dry part of the summer takes a toll on everyone equally, but in the more humid part of the summer there is an increase in heat-related mortality among a portion of minorities and lower socioeconomic strata when evaporative cooling is less efficient.

Another issue particular to the climate in Phoenix is that it's hot all summer, so the idea of one fixed threshold does not make sense. Phoenix uses the synoptic system based on oppressive air mass types, plus some local adaptations. This can present communication problems, especially when the media cannot understand why a warning is not issued any day when it is over 105˚F or 110˚F. To issue a warning at those temperatures would be crying wolf too much. This difficulty sometimes extends to forecasters themselves, who need to better understand the mechanism that triggers issuing a warning. Most of these systems are fairly complex and it's somewhat of a black box. Those who run the black box software are only presented with a red, green or yellow-coloured message from which they need to make a decision about whether to issue a warning based on a limited understanding of the system. Also from the standpoint of acclimatization, does it make sense to issue a warning at the end of the summer at the same relative temps that were used at the beginning of the summer and risk having the media wonder why it was issued.

20. Pros and cons of current HHWS: A proposed grid – *Tom Kosatsky, Direction de santé publique de Montréal.* (Powerpoint)

Tom Kosatsky led a discussion on the pros and cons of current heat health warning systems. Proposed evaluation criteria for choosing a heat health warning system were outlined as follows:

- Uses local forecasts - Encourages the use of models that are based on weather data provided locally, although this may be impractical in some places. When regional or local health and civil protection authorities can communicate on a local level, they both have a buy-in to the system.

- Timely - Allows for actions to be taken immediately (in 12 hours if there is an emergency, or 24, or 48 hours) and it allows action to be taken at various lead times into the future.

- Simple - Both public health and civil protection authorize the model and its outputs. Some users may prefer a deterministic structure and only want to know that they must take action based on the criteria the model provides, others want to understand why they're supposed to act when they act.

- Uncertainties manifest - Uncertainties of both the validity factors and precision factors should be explicit to the user, both in terms of the weather forecast (what is uncertain about the weather forecast you're receiving?) and what is uncertain about the historically derived heat versus mortality (or morbidity or discomfort) function. It is important that users can incorporate their grasp of uncertainty in public messages.

- Compatible with other advice - Are HHWS messages compatible with the kinds of advice given in US and Canada by national weather services for extreme weather and uncomfortable weather? Or do they act in opposition to advice that the public is already getting? The recommendations given in a HHWS need to figure into people's own notions of what dangerous conditions are and to any other transmitted health advice both for heat and air quality, so the warning advice does not present a conflict.

- Flexible - As understanding and accuracy of weather forecasting improves, it is crucial that this can be inputted into the system. Similarly as the evolution and understanding of the heat health function advances over time, this should also be entered into the system.

- Predictive accuracy - What do we want a HHWS to predict? Is it intended to predict just peaks in mortality, like the French and Montreal systems, or less extreme, but also important death outcomes that would occur at lower thresholds? Likewise, is it designed to predict discomfort or morbidity, or is it planned to predict mortality – and if so, in whom? A system that accurately predicts outcomes on a continuous scale (similar to the air quality indices) could be

> presented to the population as a number or a series of colour warnings, or a dichotomous outcome could be given for values above a certain threshold. Adverse outcomes to be considered include deaths due to hyperthermia, excess mortality, deaths among the otherwise healthy and deaths among the susceptible. Does heat-related discomfort affect those at rest or at effort? These outcomes have to be determined in advance. Other questions to take into consideration - are future events included as a consequence of today's weather? Is the system developed only on an assessment of the relationship between deaths *that* day and temperature *that* day, or is it based on an assessment with a lag of 1 or 2 days or more? If deaths delayed from the weather day itself are not taken into account, then one has an incomplete notion of death or morbidity as a result of today's weather. One must also be sure that the predictive accuracy of the system can be assessed. Not only historically (how well did it work in time?), but also on an ongoing basis. At the least, can one monitor the predictive accuracy of the various meteorological parameters?

At this point, the panel was asked to suggest their own evaluation criteria. Certain panellists commented that they would choose a system based on the ability of the system to reduce morbidity and mortality. According to others, the impact of interventions on outcomes is implicit in predicting the targeted adverse outcome accurately and being able to make an accurate call as to *when* to put these measures in place. It was pointed out that some type of feedback loop is necessary to gauge the effectiveness of either predictive ability or results.

Other criteria were suggested, such as cost effectiveness, ability to be communicated in simple terms, public acceptance, and integration of a partnership with different stakeholders. Considerations also should include whether one wants a system that only picks thresholds or identifies a situation at risk, and what system best fits the particular regional approach to risk management.

21. Formal comparative evaluations of HHWS of different types: techniques and their limits; *Ben Armstrong, Francesca de'Donato, Marie O'Neill*

Ben Armstrong - London School of Hygiene and Tropical Medicine's Environmental Health Research Unit (Powerpoint)

Ben Armstrong next explored the limits of formal comparative evaluations in a heat health warning system. In order to answer the basic questions of how good a particular forecast /prediction model is, and is model A better than model B, we need to estimate deaths due to heat and high numbers of deaths due to heat (dichotomous indicator of high risk such as 50-100% used in France or 20% used in Italy). According to the methods of classical evaluation, we can evaluate a system by comparing forecasted temperature versus that actually observed, and comparing predicted mortality versus observed. However, one can never directly observe excess deaths due to heat, so one subtracts the expected number of deaths (as a proxy for the normal mortality count) from the day's total mortality to arrive at the "observed excess". This introduces a source of Poisson error (biological variability) as well as a potential model error. This will bias measures of accuracy and even a perfect model may appear faulty (because death counts fluctuate in the absence of heat). When comparing methods all will suffer equally, but this brings into question whether the differences in methods can be accounted for only by chance. The problem will be worse in small cities.

Proposed more robust method comparison criterion includes comparing the sum of "observed excess" deaths in all warning days, after constraining both methods to warn for the same number of days. The method identifying the number closest to the real observed excess wins. For formal inference, to arrive at the confidence intervals and p values, one can drop all the days of overlap where the two methods agree entirely, comparing the remaining days with two independent Poison distributions.

Francesca de'Donato – Dipartamento di Epidemiologia ASL RM/E (Powerpoint)

Francesca de'Donato reminded the panel of the structure of the Italian heat health warning system before outlining the techniques used to evaluate it. The Italian HHWS was initiated in 2000 as part of a WHO/WMO demonstration project based on the synoptic air mass system. Shanghai and Philadelphia were also involved in the 2000 project. In 2003, the Rome project was developed into a national warning system. It is run by the Italian Department of Civil Protection and since 2005 has been included in a national project lead by the Ministry of Health which focuses on heat/health prevention programs. Forecasting in Italy at a national level is done by the Air Force and the military and hence, the system for collecting and diffusing the meteorological data throughout Italy is not entirely flexible. However, local and regional scale models have been developed.

The National Coordination Centre (Department of Epidemiology, Rome E local Health Authority) receives a 72-hour meteorological forecast by 8:00 a.m. each day during the summer period (May 15 – Sept 30). Two models are run – the synoptic system works well for the larger cities, but when smaller cities were integrated, the mortality counts were small and the data sets limited, so that another model, the Tappmax (maximum apparent temperature) was developed and found to be a better fit. For the synoptic model, the forecast data input is comprised of five variables (temperature, dew point, wind direction, wind speed, and cloud cover) and combined with indicators for the time of season, degree hours and days in sequence. Explicative variables in the Tappmax model include calendar month, Tappmax, interaction between Tappmax and month, holidays, and consecutive hot days. The Tappmax model produces risk tables on the basis of historical data with two levels – moderate risk (increase in mortality between 10 and 20%), and high risk (greater than 20%). The model changes each month with a different Tappmax cut-point to trigger warnings. The warning system is graded as three levels, a pre-warning/low-risk level (level 1), a high-risk level (level 2) and a high risk for 3 or more consecutive days (level 3). A simplified warning bulletin is produced for all the cities included by 10:00 a.m. and is sent to the Department of Civil Protection, which publishes it on their website. It is also sent to the Ministry of Health and they disseminate it among their networks. Each local centre identified in each city (which can be a civil protection authority or a local health department), receive the bulletin and they circulate it to their local information network, which includes hospitals, retirement homes, social services, GP's, media or others.

The two main models, as well as the warnings that are given, have been evaluated individually for the last two summers. The first stage consisted of evaluating the warning system to decide the need for 1 or 2 models for each city. Forecast data was compared with observed data and each model was re-run using observed meteorological data. Days were then classified as alarm and non-alarm days and the performance of each model was judged accordingly. In the second stage, excess mortality above 10% was classified as predicted by the model or observed. Next, days were classified as alarm, non-alarm, false-positive or false-negative days depending on actual mortality. Sensitivity, specificity, positive and negative predicted values were calculated for each city. Excess mortality during days classified as alarm, non-alarm, and false positive and false negative were compared with observed data. Bearing in mind single summers were evaluated, there was no provision made for delayed effects of heat on mortality, nor for effects of alarm intervention strategies decreasing excess mortality over time, leading to false warnings as these can be seen using different analytical techniques and for a longer time period. For each city, results from an integration of both models demonstrated, overall, a high level of sensitivity and specificity for many cities and highlighted those for which the model did not work well. The results were then broken down by an individual model, although the Tappmax and air mass based models were examined as to how well they predicted excess mortality, they were not found to be directly comparable to each other. Evidence for prevention of excess mortality due to heat was evaluated by comparing historical heat-mortality curves before and since the implementation of the HHWS in each city. Results of this evaluation will be presented in another discussion.

Marie O'Neill – University of Michigan, School of Public Health Epidemiology (Powerpoint)

Marie O'Neill described her future plans to evaluate heat and morbidity and how city programs may reduce risk funded by a grant from the U.S. Environmental Protection Agency, described in detail at the following website: http://cfpub.epa.gov/ncer_abstracts/index.cfm/fuseaction/display.abstractDetail/abstract/7884/report/0. She and her collaborators at Harvard and Michigan are investigating morbidity and heat and looking at determinants of vulnerability in the community as well as at the individual level. She is also working with a non-profit, the International Council for Local Environmental Initiatives (ICLEI), who have done a lot of work with local governments on urban heat island mitigation and are getting involved in the environmental health implications of heat exposure.

The data in this study are from a 19-year time-series of about 2 million Medicare hospital admissions for people over age 65 in 34 U.S. cities (1985-2003). The first objective is to assess cause-specific admissions during hot weather. The plan is to examine differences in vulnerabilities among admissions by co-morbid conditions, individual characteristics, and city-wide characteristics, such as city prevention programs. Other objectives include looking at the potential economic impact of temperature-related admissions and to disseminate results to city officials to foster and inform preventive actions.

A survey is currently being designed to be administered by the ICLEI in April 2007 that will seek to get information on what kind of city programs were in place from 1985 to the present. Questions to be considered include questions about heat health warning systems, whether they existed and the type, heat island mitigation activities (tree planting programs), and programs to reduce pollution from city vehicle fleets, etc. Sample survey instruments of the type collected in Europe by the WHO are being sought to facilitate collecting information in a standardized format. A research objective in this hospital admission study is to observe whether there are different associations in cities that have these programs and to examine year by year, if reliable information can be obtained on when these programs were implemented.

One member of the panel questioned the relevance of including local environmental initiatives, such as tree planting, in a study on morbidity in the elderly, rather than looking at outreach programs, and factors such as institutional and social status. Marie O'Neill replied that she'll be collecting data on features of the community that include poverty level, multi-unit housing, numbers of single person households, and other indicators of what kind of community the study population comes from.

SECTION 6

WHERE DO WE GO FROM HERE?

22. Can a HHWS incorporate both death and discomfort as outcomes to be avoided?

The participants discussed whether discomfort should be included, together with excess mortality, as a quantifiable and avoidable outcome in a heat health warning system. It was pointed out that the German heat health warning system already uses a heat stress indicator as the basic parameter, based on a physiological notion of discomfort, to prevent death as an outcome. This is in keeping with the various indices used in other heat health warning systems - such as apparent temperature, perceived temperature and humidex. All parameters seemed well honed to address the idea of discomfort, but are more speculative as to how they capture mortality as an outcome. A suggestion that discomfort is inherently implied as an outcome in the continuum along the path to mortality was supported by some, but the evidence for this was also challenged along several lines.

Monica Campbell compared heat related mortality warnings to the air pollution pyramid. In this scheme, the death outcome is the most severe but the least frequent outcome. For each death, one finds a larger number of hospitalizations and an even greater number of symptoms and discomfort. Theoretically, if a heat alert is given for the purpose of avoiding mortality, then by warning the population, one would be at the same time preventing other less severe situations. Using morbidity data to support this presents a difficult challenge, however, and a way to validate this hypothesis is currently lacking. Scott Sheridan suggested using a surrogate indicator for discomfort based on some of his own studies examining spatial variability of ambulance calls in Toronto. The study detected a very significant drop in ambulance calls on hot weekends, indicating that people were leaving the city. The notion of using something of this type as a surrogate index for discomfort was discussed.

Several participants emphasized that elderly people have been shown to be less attentive to heat stress, and their lack of apparent discomfort leaves them vulnerable to more severe heat illness. One participant introduced the idea of calling warnings for different days; one for an objective aiming to minimize death and another for an objective aimed to minimize discomfort. It was suggested that many of the causal routes leading towards mortality might follow the same path as those towards discomfort and morbidity, but for certain populations, some may be different. In the case of dehydration, for example, in hot, dry, weather certain vulnerable populations might die as a direct or indirect consequence of dehydration without prior awareness of discomfort.

23. Developing HHWS functions on the basis of archived weather forecasts as opposed to historic records of real weather parameters – *Scott Sheridan, moderator.*

An interesting discussion ensued with the meteorologists taking the point of view that using archived weather forecasts would be a flawed approach while the health professionals seemed intrigued by the idea and the climatologists were somewhere in between. The related issue of whether or not weather forecasts are indeed archived revealed that, in some jurisdictions, regular meteorological forecasts are routinely archived as are at least some HHWS mortality predictions.

Larry Robinson indicated that the Philadelphia HHWS mortality predictions have been archived. Observed mortality as recorded on death certificates has been compared to levels of death predicted, and over an entire season, it has been found that the HHWS was predicting even larger numbers of deaths that do not show up as death certificates (i.e. is this decreasing skill or increasing success of intervention programs?). Mathilde Pascal indicated that past archived forecasts were very useful in the development of the French system.

The system was developed using observed meteorological data to define the indicators and the thresholds. Afterwards, the system was tested using forecasted data provided by Météo-France. This simulation under "real conditions" allowed us to be more confident of the reliability of the system.

Glenn McGregor thought that the idea of developing HHWS functions on the basis of archived weather forecasts was worth exploring but recognized that over the years forecast quality has improved and that inconsistency in the forecast models would impact the feasibility of such an endeavour. Scott Sheridan indicated that indeed forecasts were archived but not every tweak of the forecasts. He agreed with Glenn about the inconsistency in forecasting over time and further indicated that one effect of being involved in HHWS forecasts was that forecasters started to pay more attention to dew point forecasts, once they discovered that they were important to the system, and that these forecasts have improved over time implying that there might not be a consistent quality level that would be needed to develop HHWS functions on the basis of such archived forecasts. Additionally, he was uncertain as to whether updated forecasts were archived.

Anton Haffer offered that it is a good idea to archive forecasts, but the difficulty in archiving non-numerical forecasts is that these forecasts have subjectivity in them. Some forecasters have better skill in certain parameters than others. Tony indicated that each forecaster has biases, stating that on his staff he has "webbed feet" forecasters and "dry feet" forecasters. Some of his forecasters also show a warm bias and others have a cold bias. Thus depending on who is forecasting prior to an event, uncertainty is going to be thrown into the evaluation. By contrast, if you had a purely objective forecast or a forecast directly out of the numerical models with a consistent improvement profile, you would have a much more consistent result. Denis Bourque, indicating that forecasts were indeed archived for routine verification purposes and model development, stated that he was not comfortable with the idea of using such archived forecasts as the basis for developing predictors for a HHWS, as opposed to using the actual data as the foundation. This is because the ultimate objective is get the forecasts to be 100% synchronous with the actual data and, indeed, as shown earlier, forecasts are constantly improving. The poorer forecasts of the past are history, but observed data can always be used. Christina Koppe agreed, indicating that to make a model between mortality and the environment a long (in time) data series is needed to make reliable models. Forecast models change every 4-5 years. Thus, given the longer time period needed to build a mortality prediction model, there would be several weather forecast models introducing several uncertainties. Christina offered that a better way would be to account for such uncertainties in the weather forecast component, after having developed the mortality prediction function. That is, with the mortality - temperature relationship developed and knowing the uncertainty in the temperature forecasts in precise terms, then this uncertainty is added to the mortality prediction, if the aim is to specify the uncertainty in the mortality prediction.

24. Probabilistic approaches to HH forecasting. Combination of a probabilistic weather forecast, with temperature versus health functions, to produce a joint probabilistic mortality (or morbidity, or discomfort) prediction, statistical considerations. *Ben Armstrong – London School of Hygiene and Tropical Medicine's Environmental Health Research Unit* (Powerpoint)

Ben Armstrong gave a brief overview of the statistical considerations of developing a combination of a probabilistic weather forecast, with temperature versus health functions, to produce a probabilistic mortality (or morbidity, or discomfort) prediction that reflects both uncertainties. A weakness in our current modeling procedures is that standard evaluation measures (sensitivity/specificity, MSE…) cannot be estimated directly for adverse health effects since numbers are NEVER known, even after the event.

It is his contention that uncertainties in weather forecast are carried over into predictions of adverse health outcomes in populations made on the basis of assumptions of future weather. This uncertainty is in addition to that due to (a) the weather-health model (parameter and model uncertainties) and (b) biological variation in response (usually modeled as a Poisson distribution about the expected, count given the predicted weather).

If all these sources of uncertainty are characterized probabilistically, a probabilistic forecast of adverse health effects allowing for them would be possible (either by Monte-Carlo methods or analytically).

An alternative to building up the total uncertainty from its components (weather forecast, weather-health model, biological variation) would be to use historical forecast data to model the (forecast) weather-health association, the uncertainties of which would include those due to weather forecasting as well as the weather-health model.

Tom Kosatsky commented that some decision makers would prefer a probabilistic estimate of death, rather than a deterministic estimate which does not really allow the user to access the uncertainty factor. However, this depends on which weather and health functions and distributions would be used. Mark Goldberg added that if there were very wide distributions it would be almost useless.

Ben Armstrong responded by saying that if one has very wide distributions, we would know the model has performed badly. This would indicate uncertainty in the model, not just forecast uncertainty.

Ronald Frenette suggested the distribution could be presented as a confidence band.

Monica Campbell related her experience in Ontario with the Toronto Public Health Department's air quality program. Due to many problems with inadequate preparation time for the air quality response plan, the Ontario Ministry of the Environment (OMOE) thought it would be good to have some advance notification. For a period of a few years, a smog watch was instituted by the OMOE – three days notification that sometime within the next three days there was a 50% probability of reaching the actual alert or advisory level. This ended up not being that helpful because so often when it did not move from smog watch (50% probability of an advisory) to the actual advisory, it created a lot of extra signals in the system and a disbelief in the accuracy of the predication.

Tom Kosatsky emphasized that part of the difference between a heat alert and smog advisory is that with heat, there is a massive mobilization of resources and with smog there is not. As a decision maker, he would want a good idea of the confidence band that's motivating his decision.

Norman King added that from his vantage point as a public health practitioner, explaining a probabilistic estimate of a heat alert to the media may be problematic. He concurred with Tom Kosatsky's assessment that the difference between a smog advisory and a heat alert involves massive mobilization of resources in the case of the latter. However, leading up to a heat alert, the impact isn't quite as significant, because pre-alert response plans involve only giving a public health message. The health department is warning the public of approaching high temperatures and advising people to take basic precautions. If, in that particular circumstance, the criteria of 30˚C with 40 Humidex was not attained, it's still quite hot and the message is useful. Telling people to leave their homes and come into shelters, however, requires massive mobilization of resources and causes a great deal of inconvenience to people who are displaced. He questioned what degree of certainty is needed before the department can go into the real mobilization process. Having a probability distribution can add supplementary risk information, but when does one put the whole process into effect?

25. When and how to revise weather/health forecast procedures; *Lawrence Robinson, Mathilde Pascal, Scott Sheridan.*

Lawrence Robinson – Philadelphia Department of Public Health

Dr. Lawrence Robinson related his experience with Philadelphia's HHWS. He finds the system has become more sensitive, but less specific over time. Too many warnings are being triggered by the current system and it has become necessary to find ways to revise extreme heat event forecast procedures to increase specificity. To that end, the Philadelphia Heat Task Force has as its objective to use historical data to predict future conditions, to activate the system only with the clear expectation that a heat wave condition will occur, and to implement a system that is not entirely dependent on accurate forecasts.

Currently, the system does not depend entirely on forecast prediction, or on having advance warning. Originally, elaborate pre-activation levels and graded stages of activation were put in place, but over time, it has become clear that intervention agencies have plans in place which can be activated as early as the same day. Utility companies have an intervention plan that is submitted at the beginning of the year, and emergency medical services and social services are also prepared to act within a day. A city-owned nursing home is set up to accommodate vulnerable people in the event of a heat emergency, so there is no need to mobilize emergency resources for this purpose.

At the onset of implementing the system, the specificity was much higher. Dr. Robinson believes that one reason for the diminishing specificity is that the original assumptions are no longer valid due to interventions. To make the system less sensitive, minimum and maximum parameters were set (expressed as heat indices) and before a warning is triggered, the heat episode must have a minimum 2-day duration. Episodes occurring later in the year are less likely to trigger a warning because of the effects of acclimatization. The excessive heat forecast is used more as a guide than an imperative. Professional judgment is one of the biggest inputs into the decision making process. Future plans to modify the system include using a more recent block of historical data and revising the heat-mortality function based on the new data.

Mathilde Pascal – Institut de Veille Sanitaire, département santé environnement (Powerpoint)

Mathilde Pascal commented on when to revise weather/health forecast procedures based on her experience with the French HHWS. The steps that lead to a heat warning begin with Météo-France sending tables and maps of the meteorological indicators to the InVS. If an indicator is clearly above the threshold, an alert is proposed by InVS. If the indicators are close to the thresholds, InVS checks for additional criteria. A collaborative discussion with Météo-France guides the proposal to issue an alert or not. In addition, staff from the local health authorities affected are consulted to give their input.

Some of the additional criteria to guide judgment are as follows:

- Confidence in the meteorological forecasts
- Intensity of the heat wave
- Duration of the heat wave
- Geographical extension of the heat wave
- Humidity level, wind
- Weather type
- Predicted evolution of the situation
- Wind speed and direction
- Air pollution
- Social criteria: holidays, special events…
- Real time health data

Following this collegial discussion between the health and the meteorological services, the final decision of the alert is taken by the prefects.

Scott Sheridan expressed that the redevelopment of equations and updating existing data sources can be a good thing, considering air conditioning is more common than it was in the 1970's, but to redevelop a HHWS based on the fact that people are responding to warnings would not be beneficial. He cautioned that we are not trying to predict the exact number of deaths but just to give a relative measure of risk, and that over prediction of mortality is a good indicator that the system is working. Scott urged caution before tweaking the system, using the analogy of terminating a mosquito control program once the mosquitoes are gone and then having the mosquitoes return when effective counter-measures are discontinued.

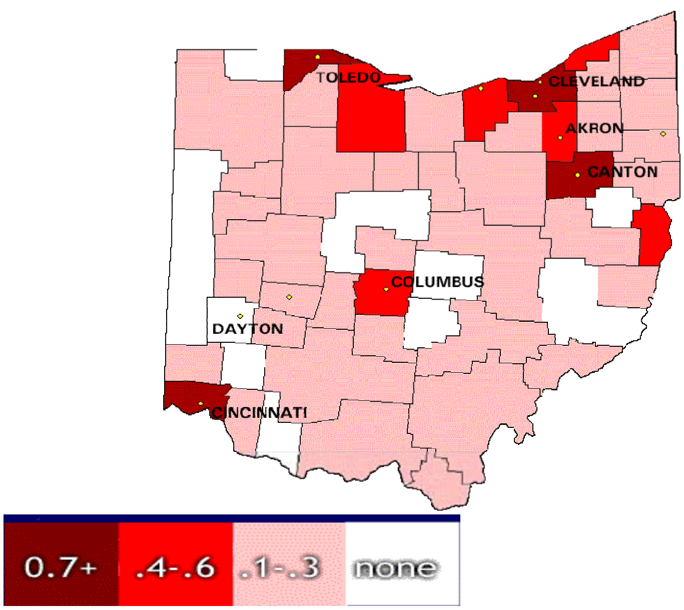
26. HHWS for cities/regions with small populations and/or little history of heat waves; *Scott Sheridan - Kent State University, Dept of Geography* (Powerpoint)

Scott Sheridan presented the findings of his project on heat vulnerability and HWWS development in smaller locations (Sheridan and Dolney 2003). Heat-related mortality was examined on a county level for Ohio during 24 summers (1975 to 1998). Total mortality data from this same period was analyzed as well. Weather was analyzed by four different definitions of “oppressive”. In this study, “oppressive” criteria were:

1. Dry Tropical air masses: 2-5 times / summer
Very hot and dry, low humidity, much sunshine
2. Moist Tropical Plus air masses: 4-10 times / summer
Very warm, humid, high overnight temperatures
3. 35°C Apparent temperature: 5-30 occurrences / summer
4. 38°C Apparent temperature: 1-10 occurrences / summer

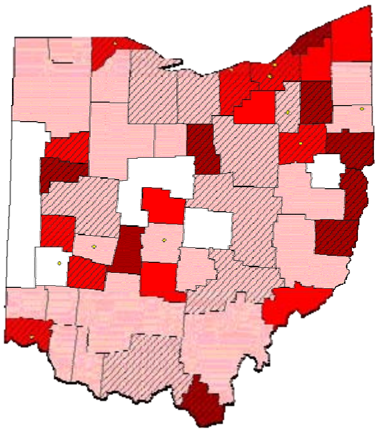
The apparent temperature (AT) thresholds used were same state-wide, while the weather indicators (temperature, dew point, etc.) of air mass types varied by locality. The analysis consisted of calculating the mean mortality response to each oppressive criterion for each county on a 0- and 1-day lag. The counties were compared to the nearest first-order weather station. In several cases, adjacent rural counties were amalgamated to increase sample size. Statistical significance was evaluated by bootstrapping.

Absolute increases in mortality
MT+

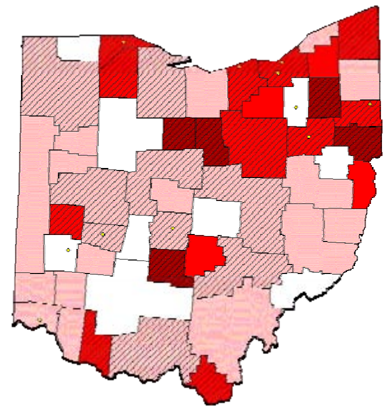


This map shows the absolute increases in mortality associated with moist tropical plus (MT+) air masses. The small counties with low populations were amalgamated with those that had similar climates. The cities with populations over 80,000 are labelled. It is clear that the absolute increases are largest in the cities.

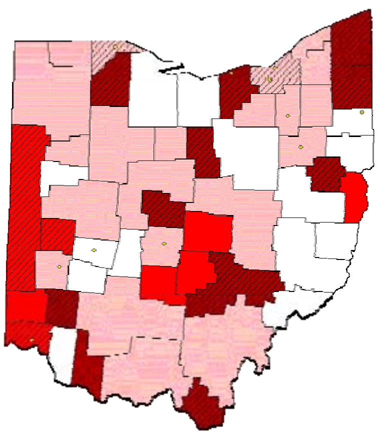
Percentage increases in mortality



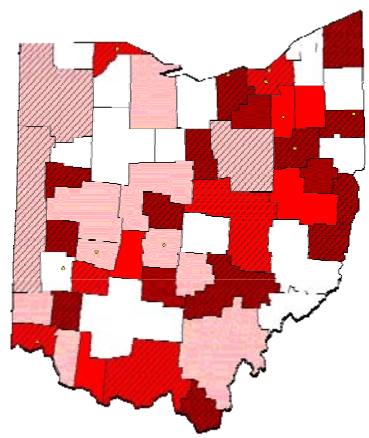
MT+



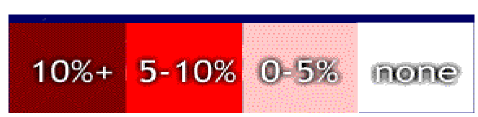
AT>35°C



DT



AT>38°C



Slashes indicate statistical significance at a=.05

This pattern changes when one looks at increases in mortality percentage relative to normal during MT+ and DT air mass days and apparent temperature thresholds of 35˚C and 38˚C. Here, the largest cites do not always have the largest increases.

TYPE	URBAN	SUBURBAN	RURAL
DT	5.2	4.8	2.5
MT+	7.4	4.9	2.7
35˚C	5.0	3.3	2.3
38˚C	10.3	4.7	3.4

Table 24.1 – Mean excess deaths by county type.

While the cities show the highest absolute total number of deaths that occur in Ohio each year from the heat, on a population basis, one sees that rural areas actually have a higher heat-related mortality per unit population, although the difference among levels of urbanization is not significant.

TYPE	URBAN	SUBURBAN	RURAL
DT	3.4%	7.4%	5.9%
MT+	4.9%	7.6%	6.2%
35˚C	3.4%	5.1%	5.4%
38˚C	6.8%	7.1%	8.1%

Table 24.2 – Mean percent increase in mortality by county type.

URBAN	SUBURBAN	RURAL
114 deaths	80 deaths	55 deaths
2.1/100,000 population	2.4/100,000 population	2.7/100,000 population

Table 24.3 – Excess mortality by county type: annual average.

This study provides evidence that heat vulnerability is not just an urban problem. By targeting our preventative measures in urban areas, the rural public may be given the false impression that rural areas are not subject to heat-related mortality. As was apparent from the preceding risk maps, variability in response across locations is significant, and not limited to urban areas.

Developing HHWS in smaller locations with many small data sets can present analytical challenges. One way to overcome this problem is to aggregate health data into as large a region as possible while assuring climatic homogeneity. Predictive equations, however, remain difficult to derive. Statistical analysis and threshold determination are not simple, especially under the circumstances where mean mortality anomalies on hottest days are frequently less than +1.

27. HHWS for countries with less technologically developed weather services and civil protection networks. *Glenn McGregor – King's College London, Dept of Geography*

Glenn McGregor spoke about his role on the WMO Expert Team on Climate and Health that is charged with the responsibility of developing, over the next six months, generic guidelines for Heat Health Warning Systems. These will be distributed to national meteorological services internationally with a focus on less developed countries, who do not have the resources to develop their own systems and/or for whom heat alerts for populations may not be a priority. Many localities may desire systems to serve only the agriculture industry. The success of putting such warning systems in developing countries will be demonstrated in pilot projects to see whether particular countries have the capacity to implement such a system or provide a response.

28. Integrating spatial variability of the urban heat island effect into HHWS; *Karen Tomic – University of Alberta, Department of Earth & Atmospheric Sciences* (Powerpoint 1 and Powerpoint 2)

Karen Tomic presented her work on integrating spatial variability into a HHWS. Because the risk from heat differs between groups, one warning may not be applicable for an entire population. The four "P'S" of risk variability are: people, place, policies and prevention strategies. When delivering intervention plans, it is important to know not only who the groups at risk are and how to reach them, but also where the high-risk places are. We know that the elderly, homeless, socially isolated and low income groups are at risk, but where are these groups? Depending on the city, in some places there are clear sectors of risk; in others the answer is not so obvious. In 1980 St Louis had a catastrophic heat wave. Only 113 died of reported heat-related causes, but this did not include excess deaths. In the United States, an estimated 5,000 to 10,000 people were reported to have died in this same extreme heat event (National Climatic Data Center 2002)

St. Louis being near the center of continental U.S., gets cold winters and hot summers. There is a lot of red brick housing, little domestic air conditioning and during the major heat wave of 1980, there was no air conditioning at the inner city hospital (Smoyer 1997). During the heat wave, emergency generators were brought in from the National Guard to cool the hospitals and shelters. Not all areas of the city were equally affected. Like many U.S. cities, the inner city is where a low-income population lives, and revenues from the surrounding suburbs do not go towards urban health services. When looking at mortality maps for the elderly during and outside of a heat wave, one can see some similar pockets of vulnerability (Smoyer, 1997; Smoyer 1998). When overlaying maps of high nighttime temperature (modified from Clarke, 1975) and poverty, again, there are areas of overlapping vulnerability. In these areas, there is a potential to target interventions at areas with high heat exposure and high population sensitivity, even on days where heat poses a threat only to comfort levels of the population in general.

One can also see from looking at housing stock which types pose a heat risk: dark brick buildings with a flat black tar roof, little sun protection from trees, wide avenues, and no central air conditioning (although window AC units are better than none). The urban heat island effect can vary considerably within a city, with different microclimates depending on geographic features. Social demographic factors can also contribute to heat risk, for example in high crime areas, people may be afraid to open their windows at night (Smoyer 1997). Access to services such as health resources and centers where people can go to cool off can also modify heat risk

One methodology to help visualize risk areas within a city are 3-dimensional topographic maps which show high risk as higher elevation (modified from Rejeski, 1993). An underlying health risk surface can be compared to a hazard-specific risk surface to identify areas of overlapping risk.

One approach to using a two-tiered warning system might include giving a general alert to the metropolitan area and a high-risk alert, whether in the city center or an urban pocket. These decisions are specific to each city depending on their resources and the priorities they identify. Targeted interventions are important because one cannot be expected to have one plan for the entire population. One way to reduce heat mortality risk without requiring extra resources is to mobilize existing resources, such as is being done in Philadelphia. Some of the challenges in creating a 2-tiered HHWS are data limitations, such as the need to obtain information (health data) on spatial variability at a census tract or neighborhood level, land use or housing proxies to indicate heat load, or actual microclimatic temperature data. Resource limitations include funding and personnel demands.

The heat risk surface is uneven. The most effective warnings and interventions need to target high risk populations AND high risk places, especially where the two overlap.

29. Integrating air quality into a HHWS. *Jeff Brook – Meteorological Service of Canada* (Powerpoint)

As an opening comment, Jeff Brook offered that in addition to mapping heat island temperatures and excess mortality onto the vulnerability (physical/demographic) surfaces of urban areas, there is also a lot of interest in mapping urban air pollution concentrations. This can be done using remote sensing tools for mapping air pollution levels for such surface based pollutants as NO_2 and SO_2 , subject to cloud obstruction and noting a resolution of 90 metres. Surface ozone is obscured by stratospheric ozone. The best current resolution is 13 to 24 KM from a single sensor on one satellite. So to try to learn about pollutant-related vulnerability, a number of other tools have been developed. Land use indicators and measurements within a city can be used to calibrate predictors from land use type data which includes road networks, traffic density, emission inventories, known sources, etc. All together that allows the provision, for places like Toronto, Hamilton, Windsor, Vancouver, Victoria, etc. of maps of air pollutant exposures that are at the 50 metre resolution scale. This resolution would be amenable to the mapping of the various risk surfaces to add another layer to where there may already be heat, social demographics, housing characteristics, etc.

Showing two views of Toronto (one clear day and one visually polluted day) from the same vantage point (across the Don Valley) the point was made that the situation is complicated. The visually polluted day was hot and particulate levels were high. On the clear day it was also fairly warm but ozone levels were high.

There are two main categories of air pollutants causing SMOG. One is ground-level ozone which is entirely a secondary air pollutant formed from precursors in the atmosphere: high ozone concentration events are strongly correlated with higher temperatures but not caused by higher temperatures. The second category, fine particulate matter ($PM_{2.5}$), is now of great interest as there is lots of information on its health impacts and is now brought into air quality indices and air quality advisories. It is not totally unlike ozone in that it is also a pollutant that has a large secondary component (it forms in the atmosphere from precursors) which allows it to be more homogenous spatially, but also has a very large primary component being emitted directly from sources in urban areas. The total particulate matter is the sum of the secondary component, largely transported from upwind areas, and the primary component from locally emitted sources. Also, the linkage to high temperatures is not nearly as strong as for ozone. There are also some other pollutants that are likely in an urban smog event including NO_2 and CO which will also build up in oppressive stagnant periods. VOCs are another class that builds up in such events.

There is the well known and documented “Acute Pollution Effect”, illustrated in slide 5, which shows a peak in mortality following a peak in particulate matter pollution. As opposed to heat, where there appears to be a population level at which point one can say there are health effects; for pollution, there does not appear to be a population level threshold where health effects are detected. While health effects (respiratory, cardiac) increase with increased pollutant levels, health effects are experienced throughout the range of levels. This presents a real challenge on managing risk because real benefits are seen from reducing concentrations across the levels. In addition to the epidemiological evidence of increased respiratory and cardiac effects of increased pollutant levels, laboratory experiments have shown physiological effects of increases in concentrations of organic carbons (at environmentally relevant levels) on diastolic blood pressure and brachial artery diameter.

There are synoptic conditions or air masses with associated hot days and nights that favour higher air pollutant levels largely through the sunshine that drives the photochemistry and enhances secondary air pollutant formation. Also, less precipitation means less wash-out of pollutants and lighter winds mean poor ventilation, stagnation and no relief from heat. In some areas, such is the case for many eastern Canadian cities, there are prevailing southerly winds transporting pollutants from larger sources south of the border. On another level, higher temperatures can enhance emissions of precursors from power generation facilities responding to peak power demands for cooling systems. Higher temperatures also result in greater evaporation of VOCs (precursor to ground level ozone and particulate matter) from anthropogenic and biogenic sources.

With regard to similarities and differences of heat and air pollution issues, it is the vulnerable members of the population that are the concern for both in regards to acute impacts. Air pollutants have chronic effects over the longer term exposure. For heat this is largely unknown and, indeed, there may be acclimatization which can be protective. There is not likely any protective physiological adaptation with air pollution. Advisories exist for both, but there may be differences in the advice given as well as similarities. Finally, high air pollution is more likely to occur without heat, as opposed to heat without elevated air pollution.

Forecasting of Air Quality events is strongly dependent upon meteorology. The main ingredients do vary from place to place but are fairly well known by local forecasters, who studied local air quality and have recognized what conditions result in high local concentrations. Nevertheless, accurate prediction is quite a challenge with a high potential for false alarms. The standard tools are models coupled with numerical weather prediction models. These currently only show acceptable predictive capacity on a regional scale, as opposed to a local scale where there is a need for empirical models for improved local-scale information. The model used in Canada is the CHRONOS model, which shows some regional predictive capacity, but tends to over-predict ozone and particulate matter levels generally. The exception is in mean $PM_{2.5}$ concentration prediction in the London and Sarnia area, where the predictions are close. In general, mean concentration levels are better predicted than maximum levels. Also, predicted ozone concentrations in rural areas are better than predicted concentrations in urban areas. Models are not at a stage where they are making use of the current ozone data that is now broadly available across North America. The CHRONOS model starts with emission fields to predict concentrations and time steps them forward to get pollution levels, updating meteorology as it goes forward, but there is still no system for chemical data assimilation on a regional scale in place. A simulation methodology is currently being worked on whereby AIRNOW (containing hourly ozone data from throughout

North America) ozone information is assimilated with model predictions to produce idealized ozone fields, which then can be put into the model to make the model more accurate. This combination (AIRNOW+ CHRONOS) holds considerable promise for the future.

The issue of integrating air quality with heat health warning systems is problematic since, as was previously stated, not all heat events have poor air quality and poor air quality does not necessarily imply hot conditions. In Eastern North America, in trying to develop empirical associations between heat and air quality, there is a decoupling or change in the relationships with changing emission fields due to the imposition of NO_x controls, or inclusion of $PM_{2.5}$ in systems. Thus, with emissions changing with policy due to interventions, it is not possible to set one condition and expect it to hold like you might with weather and mortality. Also as part of this integration issue is the issue of harmonizing messages to the public.

There has been a lot of work done between Environment Canada and Health Canada to develop an Air Quality Health Index (AQHI) for Canada, which is now being piloted in various locations. The website for the B.C. pilot is http://www.airplaytoday.org/. The AQHI is based on epidemiological data from across Canada and also based on multiple pollutants considered simultaneously and linked to a health end point then normalized into an index. It would be technically feasible to include “Humidex” or temperature and humidity in the AQHI. This may be of use to health agencies in planning and preparing for hot, high pollution events where the combined stress might be quite significant but how this is then messaged to the public could be quite a challenge.

It was noted that a severe heat event could result in the doubling of daily mortality while a significant air pollution event statistically results in .5 deaths in a normal 40 death per day situation. Despite this statistically smaller per event impact, the pollution impact is broader across the country, resulting in about 6900 deaths per year in Canada.

30. Integrating ongoing health surveillance (example current real-time daily deaths, or ambulance calls) into a HHWS. *Francesca De'Donato, Shak Hajat, David Buckeridge*

Francesca de'Donato – Dipartimento di Epidemiologia ASL RM/E (Powerpoint)

Francesca de'Donato explained that thanks to the availability of real-time mortality data in the Italian HHWS, ways to use this information to assess and improve the system prediction were developed. Her team developed an autoregressive model for the prediction of daily mortality. For a selection of cities, autoregressive HHWS models have been run in experimental mode in 2005-06, but not yet integrated into the HHWS. To estimate daily mortality, the model uses both observed and predicted meteorological data, as well as observed mortality data from the rapid surveillance system collected during the three previous days. The advantage of this is that it can account for possible short-term changes in population response which cannot be readily estimated by traditional models.

Mortality and meteorological data from the last 5 years were used to define baseline daily mortality, and other variables include:

- Autoregressive component = previous day mortality from rapid surveillance system (complete number 2-3 days prior)
- Temperature and Apparent temperature (min, max) **Lag terms considered for temperature: 0, 1, 2, 3*
- Number of days with Tappmax>90° percentile – used as threshold for definition of a heat wave
- Order of heat wave, persistency, interval (days) between heat waves
- Calendar month
- Trend
- Day of the week

Excess mortality is defined as the difference between observed and baseline mortality. Baseline mortality is calculated as the mean daily mortality of people over age 65 by day of the week. City-specific models were developed for Bologna, Milan and Rome and have been experimental since 2005.

Results from Rome in 2005 show that predicted mortality was captured well in the early part of the summer, but that the system performed less well in the later part. Results from a smaller city, Bologna, show a somewhat reduced correlation coefficient. The evaluation was carried out by comparing predicted warnings with observed warnings defined by observed temperatures and observed mortality (days with excess mortality >10%). Sensitivity, specificity, negative and positive predicted values were calculated for the three experimental cities.

Shakoor Hajat added that in the UK, the meteorological office has set up a health forecasting system to predict hospital admissions mainly in the winter season (http://www.metoffice.gov.uk/health/). Work from the London School of Hygiene and Tropical Medicine has demonstrated that the level of admissions on any given week can, to a large extent, be predicted by the previous week's levels.

David Buckeridge commented that some very promising work has been done looking at age groups in temporal surveillance. When examining certain causes such as influenza, there's been some groundbreaking research on a potential presaging effect on other groups (Brownstein et. al, 2005). Younger children aged 3-4 years demonstrated a mean lead-time of approximately three weeks in seeking health care services as compared to other age groups. So there might be similar relationships here. It may be of value to focus on subpopulations even within a database.

Mark Goldberg added that he thought that the Italian models are predicting very well, they might not be predicting well enough for the purposes of producing warnings, but in comparison to models that just include weather and air pollution, the R^2 values are quite high.

31. Modifying warning/action thresholds based on weather and mortality experience during the season to date. *Francesca de'Donato*

32. Can we evaluate the impact of HHWS, and how. *Francesca de'Donato, Scott Sheridan*

Francesca de'Donato – Dipartimento di Epidemiologia ASL RM/E (Powerpoint)

Francesca de'Donato described the Italian experience of revising HHWS models based on updated weather and mortality data. After the severe heat wave of 2003, some northern Italian cities that were previously not exposed to heat, such as Turin, exhibited record breaking temperatures that had not been recorded in 150 years of meteorological data. The previously existing models would not have been able to capture the heat-related impact that was observed that year. Revision of air mass-based models included the redefinition of models, and extending the time series to include 2003 data. As well, mortality predictive algorithms for all air masses were developed, not just oppressive ones in order to have a continuous prediction of daily mortality. This was done especially to account for the impact of borderline air mass that occur following an oppressive air mass, which otherwise would have been excluded and warnings not issued. Integrating the air mass model with Tappmax regression model was carried out for the definition of warning levels, and improvements in forecast information were initiated.

In Turin there were only 2 instances of dry tropical (DT) days in the original 10-year data, but when the summer of 2003 was included, there were about 38 more, which improved the algorithm without essentially changing it that much. Another issue that has come up as a result of recent weather patterns is when there are very long periods of oppressive air masses and you are considering consecutive days as one of the components in your predictive algorithm, and the values continue to climb, it was decided to set a ceiling limit, which was set to 5 days.

Scott – Statistically, as Francesca pointed out very well, when you redefine a model after an extreme event all criteria tend to change. It's hard to say if the model becomes more appropriate, as a model that is tuned to an extreme heat event may not end up being as good a predictor during a more common, less extreme event. In Italy, we modified the consecutive day because, unlike an ideal heat wave where it gets oppressively hot for 10 days in a row and you can count them easily, more commonly we have a couple of oppressive DT days, followed by a couple slightly cooler but still very warm days that end up just below a threshold, and then the offensive air mass returns. In situations such as these, and it doesn't really make sense to restart the sequence, as the oppressive weather never really left. To account for this, we did a different day in sequence, where you increment up one if an oppressive air mass is occurring, and if you have a near-oppressive air mass you decrease the count by one, and then if an offensive air mass returns, increase by one again. Thus, instead of starting the counter at zero again, it would still maintain a certain value.

Francesca De' Donato continued her discussion of the Italian HHWS by looking at the evidence used to evaluate the system. The 12-city data from the summer of 2006 demonstrates a short heat wave in June and a prolonged heat wave in July affecting most of the country. Parameters used to evaluate the number of false positive warnings, false negatives, true positives and non-alarm days include an alarm day defined as the Tappmax index above the 90th percentile and more than 10% excess mortality predicted**.**

TEMPERATURE FORECAST	**TEMPERATURE OBSERVED**	**PREDICTED MORTALITY**	**OBSERVED MORTALITY**
No alarm	No alarm	No alarm	No alarm
True negative			
Alarm	alarm	Excess deaths	Excess deaths
True positive			
Alarm	No alarm	Excess deaths	No excess deaths
False positive			
No alarm	alarm	No excess deaths	Excess deaths
False negative			

Using values of excess mortality on days classified as alarm (true positive), non-alarm (true negative), false positive and false negative using observed and predicted meteorological data, comparisons were developed for Rome, Bologna, Milan, and Turin in the summer of 2004. Results show that for Rome, there was clearly elevated excess mortality on false negative days, which seems to support the effectiveness of the interventions. This observation was not as clear for the other cities. While the HHWS in Rome had been operational for two years at the time this data was collected, for the other 3 cities, this was their first year with a HHWS. This, and a relatively small data set, may account for some of the apparent ineffectiveness of these systems. Data from 2005 showed the HHWSs for Rome, Bologna, Milan, and Turin behaving more along predicted patterns, with elevated mortality on alarm and false negative days, and decreased mortality on non-alarm and false positive days. Similar analyses were developed for 7 other cities but given limited data, results were not clear.

Another evaluation technique initiated in 2006 involved looking at comparisons of apparent temperature mortality curves over time (Michelozzi, Sario et al. 2006).

33. Improving communication between weather services and health departments/civil protection authorities (and the public): what should be communicated and how. *Denis Bourque, Mathilde Pascal, Scott Sheridan, Norman King, Anton Haffer, Larry Robinson.*

The panel exchanged views on improving communication between weather services and health departments, civil protection authorities, and the public, including what should be communicated and how. Denis Bourque opened the discussion by emphasizing the critical nature of the relationship between the weather service and health authorities when providing advance notification of a heat event, and stressed that it is essential that a liaison exists. Persons present at this workshop all indicated that their health and meteorological organizations work closely together (except Italy), and agreed that each side must understand what the other needs and is able to deliver.

Mathilde Pascal from the InVS shared the view that the key to good communication is to be transparent, to have common objectives, vocabulary and data. In France communication works quite well because both sides feel they are working together on a common project and they understand each other.

Tony Haffer pointed out that there is the obvious communication at the professional level between the professional health person and the professional meteorologist, but that it is also very important to work with the public information face of health services that deals with the media. From a meteorological standpoint the media representatives must be able to translate what we meteorologists are trying to say into terms understandable to the health community as well as the public. When the translation is effective, it benefits both the meteorological and health services communities. Also helpful is to have joint workshops with the media and both the health and meteorological communities. We need common objectives, know what the other's language is and be able to communicate, because the bottom line is, all of us on the science side of things can do things perfectly but if we don't communicate effectively, it's all for naught.

Norman King from the Direction de santé publique in Montreal added on a similar note that a few years ago he had a media briefing with Environment Canada, the regional health authorities and the media so they could understand what was on the horizon for the summer. The provincial Occupational Health & Safety Commission was invited as well because issues around health safety at work are quite different. When public health authorities tell people on hot days to be less active during hot hours, the workers' Health and Safety Commission doesn't give the same message. This event was quite successful and since then, the media always consults the public health authorities to learn what's going on, and they transmit the appropriate messages very efficiently to the general population.

Scott Sheridan commented in reaction to statements made earlier about targeting, that there needs to be a differentiation between targeting where one places resources in different locations versus targeting people within a general message. In survey work he has done, a significant percentage of people said they did not modify their behaviour because they felt that the message was intended for someone else. When a warning is targeted at a specific locality, people not in that locality will think it doesn't apply to them. If one specifically targets vulnerable groups in messages, people will think of any excuse why the message doesn't apply to them. Therefore, while targeting and GIS work are excellent for resource allocation, one should be cautious about over-targeting specific groups within general messages.

Denis Bourque added that sharing vocabulary and objectives becomes crucial in situations where there are two or more organizations involved because, for example, one never knows which organization is going to be approached by the media with inquiries during a heat wave. It is a common experience of the Meteorological Service of Canada to be approached by the media asking for the health messages when there is a heat wave or an air quality situation occurring; having a shared vocabulary and a shared understanding becomes crucial at these times.

Larry Robinson also commented that in Philadelphia they hold a press conference at the beginning of every year and prepare a briefing to avoid having the press make up the copy and get it wrong. We give them exactly what we want them to say and it has to be done in such a way that they can't change it, for instance, as short sound bites like "drink water", "the heatline number is…"etc. We find that the media plays those same messages over and over.

34. Where do HHWS go from here?

Towards the end of the workshop panellists were invited to share what they have learned from these last two days and what we should do next. Michel Ducharme began by commenting, from a physiologist's perspective, that system developers were going in the right direction. One thing that is crucial is education of the population – if you give a warning, what should the public do? A warning system should be developed in parallel with an education program.

Ken Parsons commented that the advice we are giving out is fairly common sensical, but it does change. We should evaluate the advice based on fundamental thermal-physiology and it would be fairly easy to do in research terms. It would likely confirm that the advice we're giving currently is more or less correct, but it would be helpful to have a scientific basis for that. In terms of thermo physiological research, it may be that we've investigated insufficient numbers of subjects that could be classified as being vulnerable to heat and even insufficient numbers of normal people as opposed to fit, young males and military personnel. In terms of acclimatization and accommodation, our research has focused on strenuous exercise under extreme conditions, rather than what is in keeping with the normal heat imposition at different times of the summer, so there is a need to investigate more low-level responses. "If we ground our strategies in basic thermo-physiology, I think there's something to be achieved there," he said.

Ian Blanchard stressed consistent messaging or key messaging as an important issue. Because so few cities in Canada have HHWSs in place, now is the time to harmonize the messaging for all cities. When more cities come on line and develop warning systems it will be harder to change the messaging. Obviously the thresholds will be different between cities, but the messages should be consistent.

Marielou Verge found this to be a very informative workshop. A good mix of both sides was presented and for Health Canada, there is a lot of interest in the capacities of the municipalities to adapt to climate change and what future direction should be taken, both on the municipal level and on the individual level as well. One issue that needs attention and perhaps more research, is how people are reacting to the message of how to adapt behaviour. We need to adapt the messages to better focus on vulnerable people. Maybe we need to adapt vocabulary to different population groups.

Shakoor Hajat felt that there could almost be a two pronged attack. There certainly needs to be specific warning systems, but many populations have adapted to heat without these kinds of warning systems. We need to be instrumental in gradually changing the mentality of the way people assess the dangers of hot weather. In addition to warning systems, we could do a lot to reduce the heat slope observed throughout the summer. Examples of these would be better general education of the dangers of hot weather, and long-term changes in housing stock. At the London School of Hygiene and Tropical Medicine, his group is currently evaluating the U.K. system. As a part of that evaluation, they will be identifying people's awareness of the system and their behaviours in response to heat.

Mark Goldberg responded that he had the idea of conducting targeted panel studies for the summer and trying to get a better handle on what happens to people, not just during heat waves, but looking at a large range of temperatures. By using multi-city panel studies, studying normal people, people with specific health conditions, (there doesn't need to be any intervention, all one needs is observational studies) we could gain quite a lot of information on physiological profiles of people as the temperature varies.

Christina Koppe believes it is important that people who run or develop HHWS have clear objectives in mind and know what it is they want to prevent. Should it only avoid mortality under extreme conditions, or should it be a more general education for the population, so the population becomes more adapted and knows preventive measures by itself? This is a philosophical question and everyone needs to answer this question individually. More should be known about processes such as adaptation and acclimatization. From a theoretical approach, how exact do you want to be? In the German system, interventions taken are perhaps less of a key issue than refining instrumental control and quality management.

Jason Samenow identified education and outreach as key issues for a number of reasons. Many different terms are used – warning, alert, advisory, heat health warning systems or heat watch warning systems, etc. He wonders whether the public really understands the distinction between those terms. Perhaps we need to do more focus groups to clear up public confusion.

When asked about the cause of reduced mortality in Philadelphia, Dr. Robinson replied that it was primarily due to putting the issue on the radar and raising the level of awareness of heat dangers in the public. He was also intrigued to discover that several of the group were working independently on spatial analysis, so that may be another promising area of research.

Marielou Verge brought up the issue that in Quebec, good surveillance tools for health indicators are available. An area for research making use of that information might be using two indicators, one meteorological and a real-time health outcome indicator. For example, we could combine ongoing mortality data or other health information with our regular warning system based on meteorological information to see how we can modify it to provide better data based on the other. Another use would be perhaps to monitor the response of vulnerable population sectors under less than extreme conditions, on the basis of health indicators.

Along these same lines, Ian Blanchard said he hopes to be looking at meteorological issues and EMS deployment data. He has quite intricate deployment models in Calgary and he is sure that meteorological data will enhance those models significantly.

Marie O'Neill stated that maybe interventions should be examined separately at a future workshop, because many issues remain to be clarified. Clearly, the message that is being given in the U.S. is that the use of fans is discouraged, while in the U.K., they are accepted. At least in part, this conflict arises from thermo-physiological studies in controlled environments. However, what is happening in the real world is yet to be thoroughly understood. We should attempt to reconcile those messages based on research.

Tom Kosatsky agreed whole-heartedly, but these issues are beyond our agenda here, which is the warning threshold issue. Here we have been looking at *when* authorities should react. One needs to understand how authorities react, what lag time is needed, and what level of confidence they need in models used to determine when to react. Certainly, intervention measures are a big issue. The nature of the response and the nature of public education and prevention programs are far more important than how you pick specific thresholds. This should be the subject of other discussions and shared experiences. Other areas that need to be addressed in future meetings are some of the things that Ken Parsons brought up – having a better notion of the physiology. He added that many avenues have been brought to light at this meeting, such as looking at the collective experience so far, doing a review of some of those things, doing panel studies, maybe clinical trials and trying to reconcile discomfort information with mortality data. These issues go beyond the simple, or not so simple, issue of picking a threshold, which has been the focus of our workshop.

Scott Sheridan expressed his satisfaction with the workshop and added that this is a broad continuum of work from the understanding of the heat-health relationships involved to the evaluation of the HHWS. A lot of the panellists are experts and have been working on separate little components, but some of the information on physiology is very foreign to him, coming from a meteorological background. We should be encouraged to have more cross-disciplinary understanding, and to keep in mind that our own little realms are a small component of the whole.

35. Workshop wrap-up and plans for documentation and follow-up.

Tom Kosatsky wrapped up the workshop by asking the panellists their ideas about where we go from here. He outlined plans to produce a report bringing in all of the ideas, many of them very innovative, which have come forward in this workshop. As well, sufficient material was presented in the workshop to potentially publish some group papers detailing the state of the art and future directions for HHWS. Those panellists interested in sharing the information they presented at the workshop or contributing to writing up some of the issues discussed are invited to do so.

Glenn McGregor brought up the point that at the political level, it is important to raise heat as a hazard to an equal level as other hazards for its impact on society. Right now it is a poor second cousin compared to floods, droughts, volcanoes, etc. Once we have raised it to an equal level, in some ways the problem will take care of itself in terms of public education programs. He agreed that education is crucial. People and societies are interested in their own well being, and an educated society will take care of itself. This tends to be done at a political level and it might need to involve people who are not attending this workshop.

Tom Kosatsky replied that in some ways the participants at this meeting are not those involved in the political arena. He expressed that he really wanted to invite people with expertise whose voices haven't always been heard in developing heat adaptation approaches. It was very important that everyone working on these issues be present here and all contribute to this process, not just those who have entered into the political process. People working on this issue at the policy making level certainly have a role to play there, as well as any of the rest of us who have contact with people at other levels who will put the things that we've come up with into policy.

Ken Parsons believed that we should approach this as an international issue. Certainly, the extreme heat issues in places like the Far East and India present the same kinds of problems that they do elsewhere on the globe. Glenn McGregor reminded the group that the WMO commissioned generic guidelines written on HHWSs and perhaps this represents a step in the right direction.

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