Environmental Health

The French Heat and Health Watch Warning System: principles, fundamentals and assessment

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List of abbreviations

Anap: Agence nationale d'appui à la performance des établissements de santé et médico-sociaux (National agency for supporting the performance of healthcare, medical and social institutions)

ARS: Agences régionales de santé (Regional Health Agencies)

BMI: Biometeorological indicator (BMImin=BMI for minimum temperatures, BMImax= BMI for maximum temperatures)

Cica: Comité interministériel canicule (French Interministerial Heatwave Committee)

Cire: Cellules inter-régionales d'épidémiologie (InVS Regional Cells)

Credoc : Centre de recherche pour l'étude et l'observation des conditions de vie (French Research centre for the study and observation of living conditions)

DGS: Direction générale de la santé (French General Directorate of Health)

HHWWS: Heat and health watch warning system

Inpes: Institut national de prévention et d'éducation pour la santé (National Health Education and Prevention Institute)

Insee: Institut national des statistiques et des études économiques (French National Institute of Statistics and Economic Studies)

Inserm: Institut national de la santé et de la recherche médicale (National Institute of Health and Medical Research)

Miga: Mise en garde et actions (Warning and action level of the National Heatwave Plan)

Oscour®: Organisation de la surveillance coordonnée des urgences (Organization of the coordinated monitoring of emergencies).

NHP: National Heatwave Plan

Samu: Service d'aide médicale urgente (Emergency Medical Assistance Services)

SOS médecins: Emergency General Practitioners Service

Sursaud®: Surveillance sanitaire des urgences et des décès (Health surveillance of emergencies and deaths)

SRVA: Serveur régional de veille et d'alerte (Regional monitoring and early warning server)

Td: Dew point temperature

THI: Thermohygrometric index

Tmax: Maximum temperature

Tmean: Mean temperature

Tmin: Minimum temperature

1. Introduction

The heatwave is a well-known weather event that nevertheless lacks a standardized meteorological definition. The summer 2003 heatwave was the most intense recorded in France since the 1950s, with a period of exceptionally extreme heat occurring during the first fortnight of August. Prolonged, severe ozone pollution was added to this episode.

In the immediate aftermath of the heatwave, the French Institute for Public Health Surveillance (InVS) conducted and contributed to a large number of epidemiological studies that aimed to:

- determine the excess mortality rate from all causes attributable to the 2003 heatwave in the largest French cities and on a national scale (National Institute of Health and Medical Research (Inserm) study [1,2]);
- identify risk factors for mortality in elderly people who died at home and in institutions, through two large case-control studies [3,4];
- determine the relative impacts of ozone and temperature on mortality, in the nine cities where the air and health surveillance programme is operating [5].

This research enabled to estimate the number of excess deaths compared to previous years, which was 14,800 between 1st June and 20th August 2003, representing a 60% increase compared to the expected mortality. While the whole of France was affected, excess mortality affected urban areas to a greater degree. The mortality analysis showed that elderly people (over 75) and very elderly people were the main victims. In subjects under the age of 45, the only causes of death that increased were those directly related to heat and ill-defined and unknown causes of mortality, with the increases seen only among men. Three groups of causes of death were distinguished in subjects aged 45 and over [6]:

- Causes directly related to heat (heatstroke, hyperthermia and dehydration), the relative increase of which was massive (number of deaths increased 20-fold or more depending on age and sex).
- Other causes for which the excess mortality was extremely marked: nervous system diseases, mental disorders, diseases of the respiratory tract (including pneumonia), infectious diseases, diseases of the genitourinary system, endocrine diseases and ill-defined and unknown causes of mortality.
- Almost all other medical causes increased but less markedly.

Studies have also shown that while the measures required in order to limit the impacts of heat were relatively simple to implement, they were not well-known and were hard to manage during a crisis. In order to improve the heatwave response, the French Ministry of Health developed a National Heatwave Plan (NHP) in 2004. The NHP defines actions aimed at preventing the health impact of episodes of extreme heat. It includes recommendations for different stakeholders: health professionals, key actors in the social sphere, etc.

Some NHP recommendations have a legal support (setting up the institutions caring for elderly and vulnerable people to help them to cope during heatwaves [provision of a cool room in the management plans for elderly people, etc.], and creation of a file of vulnerable people in town halls). While the emphasis is on prevention throughout the summer, certain actions are reinforced when a heatwave is expected. Specifically, these include communication with the public, mobilization of health professionals and social workers making contact with vulnerable people.

The NHP includes a Heat Health Watch Warning System (HHWWS) identifying actions to be implemented according to the meteorological context. The system was designed by InVS and Météo-France (the French national weather forecast service) on the basis of a framework agreement signed in early 2004 to facilitate the implementation of preventive and warning mechanisms for weather-related health hazards.

The HHWWS has classified the NHP actions according to three levels:

- The **seasonal surveillance level** corresponds to the period from 1st June to 31st August. Each day during that period, InVS monitors weather and health indicators in collaboration with Météo-France. Before the start of the seasonal surveillance period, the national and local services take part in an exercise to test the operational arrangements. A call centre providing information and guidelines in the event of extreme temperatures is operational (free-phone number).

- The **warning and action (Miga) level** is triggered by department prefects if the forecasts exceed the thresholds established in the HHWWS, on the day itself or one to three days in advance. It makes the following provisions, as appropriate:
  - Preparation for staggered implementation of the preventive measures detailed in the NHP if the alert is triggered for a forecast heatwave.
  - Implementation of the appropriate sanitary and social measures locally and nationally if the alert is triggered for an actual heatwave: information on preventive measures, support for high-risk people as defined in the plans and if necessary, triggering "white plans" in hospitals and "blue plans" in retirement homes (particularly for the purposes of recalling staff or opening additional beds).

- Finally, the **maximum mobilization level** corresponds to exceptional situations beyond the scope of the health sector, which require the mobilization of all actors involved in the NHP. It is triggered by the Prime Minister on the recommendation of the Ministers of Health and the Interior.

2. Principles of the Heat and Health Watch Warning System

The purpose of the Heat and Health Watch Warning System (HHWWS) is to identify heatwaves that are likely to have a major health impact, in order to enable the rapid implementation of prevention and management measures.

It is based on monitoring forecasts from biometeorological indicators (BMIs) and a system of departmental alert thresholds.
If the weather forecast indicates a high enough risk that the alert thresholds could be met or exceeded over a minimum period of three days, InVS and Météo-France recommend activating the "warning and action" level of the NHP.

Meanwhile, in the event of a heatwave, health indicators are monitored (deaths recorded by civil registries, calls to "SOS médecins" (emergency house calls) or the Samu (Emergency Medical Assistance Services), attendance at hospital emergency departments for all causes and for heat-related conditions) in order to assess the potential impact so that, if necessary, the relevant services (health, management, communication, etc.) can adjust the management measures.

Feedback from experience is collected annually, and regular assessments are used to improve the system, in terms of logistics, organization or scientific matters.

3. The weather warning system

3.1. Choice of indicators and meteorological thresholds

The method used to design the warning system is detailed in the 2006 HHWWS report [7,8]. Full details of the results are presented in the 2004 and 2005 HHWWS reports [9,10].

Initially weather indicators and thresholds were calculated in 14 pilot cities: Bordeaux, Dijon, Grenoble, Le Havre, Lille, Limoges, Lyon, Marseille, Nantes, Nice, Paris, Strasbourg, Toulouse and Tours. These are major French cities regularly spaced throughout mainland France and representative of the different climates. The study period covered the years 1973 to 2003.

Over this period, the climate variables of the studied cities showed considerable fluctuations. The mean temperatures between 1st June and 31st August over the 1973-2003 period vary from 12.5°C (Lille) to 19°C (Nice) for the minimum values and 21.2°C (Lille) to 28.5°C (Marseille) for the maximum values.

Several potential heatwave indicators were tested for the HHWWS: minimum, maximum and mean temperatures (Tmin, Tmax and Tmean), a mixed indicator combining the minimum and maximum temperatures, the mean dew point temperature (Td) and the thermohygrometric index (THI) (based on temperature and relative humidity). The minimum and maximum daily temperatures were provided by Météo-France.

These meteorological data were compared to daily excess mortality. This was estimated from data on daily mortality from all causes collected by the French National Institute of Statistics and Economic Studies (Insee) for the period 1973-2003. The mean mortality for a given day, or "baseline" of mortality, was calculated as the mean over the previous three years of the smoothed daily mortality. Different smoothing windows were tested.

Daily excess mortality, expressed as a percentage, was calculated using the following formula:

$$e[d,y] = 100 \times \frac{mortality[d,y] - baseline[d,y]}{baseline[d,y]},$$

where *d* represents a day and *y* a year.

To compensate the statistical impact of the low number of deaths and the substantial variability in mortality in the smaller cities, an excess mortality variable was also calculated from a three-day cumulative mortality. Data were also analyzed so as to test the possibility of a gap of several days between temperature and mortality.

Tests were conducted in each city based on the meteorological indicators and daily excess mortality percentages. These tests consisted in calculating for several possible values[1] of weather thresholds and previously defined excess mortality levels, the total number of alerts, distinguishing between "real alerts"

[1] - 30 values for the Tmin, Tmax, Tmean, DTmean (difference between the mean temperature of the day, and the mean temperature observed over the last 30 years on the same day), Td and THI indicators, increasing in 1°C increments.
- 400 possible combinations for the Tmin and Tmax indicator.

(corresponding to the days where high temperatures are associated with high mortality), the "false alerts" (days where high temperatures are not associated with high excess mortality) and "missed alerts" (days when excess mortality is high but not temperature). Through comparison with a diagnostic test, the indicator test results gave rise to sensitivity and specificity calculations.

Excess mortality levels were chosen in consultation with system users. They were set at 50% for Paris, Lyon, Lille and Marseille and at 100% for the other, smaller cities. Lower thresholds could not be considered because of the excessive variability in mortality in medium-sized cities, where 20% of daily mortality was sometimes equivalent to less than one death, meaning that excess mortality rates under 50% and even 100% could be due to any event other than a heatwave, such as a car accident. Finally, these thresholds match the definition of major epidemic events listed in the national heatwave plan.

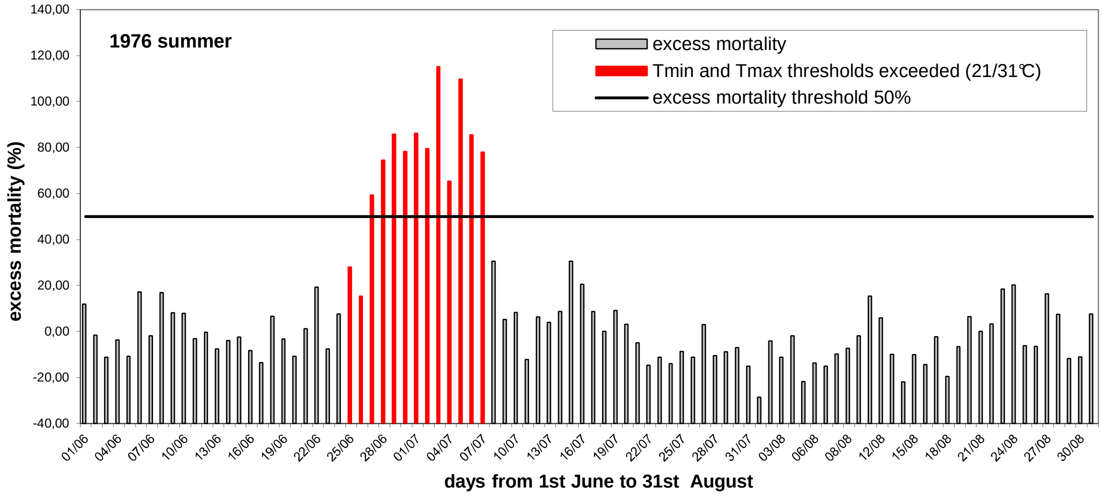
The most relevant indicator is the one which achieves the best compromise between good specificity and good sensitivity. It is also necessary, for reasons of simplicity of the system that this indicator be common to all cities. On this basis, the most effective indicator in all cities was the combination of minimum and maximum temperatures averaged over three days. It was therefore selected for all pilot cities. It is abbreviated to BMI, for "Bio Meteorological Indicator".

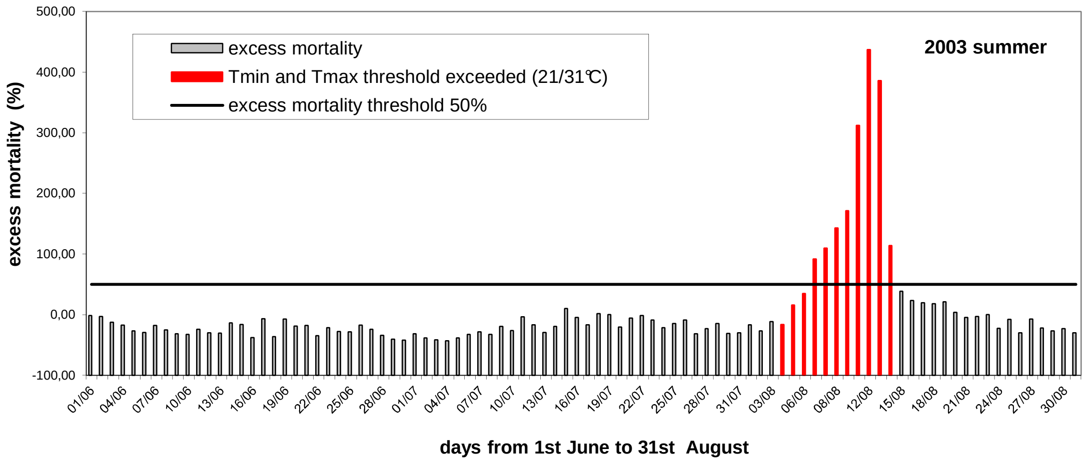
The chosen indicator is therefore the pair (BMImin, BMImax), where BMImin is the sliding mean over three days of minimum temperatures, and BMImax the sliding mean over three days of maximum temperatures (Bio Meteorological Indicator = BMI).

Once the indicator had been chosen, the warning thresholds were selected for each city with the objective of combining a minimum of missed alerts with a minimum of false alerts that would discredit the operational system. For example, in Paris the pair selected as the threshold for the average minimum and maximum temperatures was 21°C-31°C.

The chosen system was then tested retrospectively for each city, for the years 1973-2003. It showed good capability for detecting extreme heatwaves for which excess mortality was actually observed (specifically 2003, 1983 and 1976). Figure 1 shows reasonably good correlation for Paris between the system's "proposed alerts" and the actual dates when excess mortality thresholds were exceeded: in 1976 and 2003, the temperature thresholds were exceeded three days before excess mortality occurred, and both were consistent until the moment that would have corresponded to the lift of the alert.

Figure 1 - Simulation of meteorological thresholds exceeded for 1976 and 2003 in Paris: the days identified as alert days by the current system are shown in red

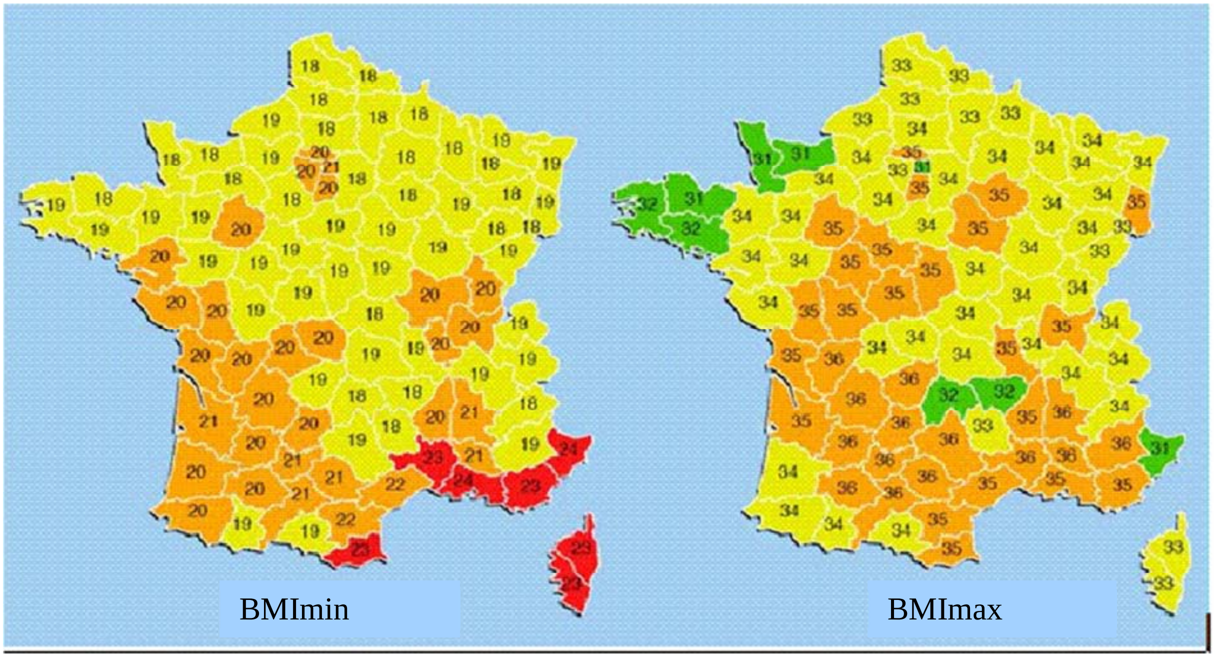




These thresholds subsequently had to be extended to the whole country. As it was not possible to conduct a temperature/mortality analysis for each French department, particularly because of very low numbers of deaths in small towns and a consequent lack of statistical power, the selected approach was to investigate whether the thresholds calculated for each pilot city were consistent in terms of temperature distribution percentiles. Different percentiles were calculated. The 99.5 percentile proved to be the closest to the previously determined thresholds [7]. Consequently, after selecting a reference meteorological station for each metropolitan department, the 99.5 percentiles of indicator distribution over the past thirty years were calculated. The minimum and maximum thresholds obtained in this way (BMImin and BMImax) are presented in Figure 2.

The thresholds found by this simple approach were confirmed by searching for thresholds using an alternative method in six cities (Paris, Marseille, Lyon, Limoges, Nantes and Strasbourg). This method consisted in modelling the link between meteorological and mortality indicators using generalized additive models, to select the percentile on the basis of which excess mortality exceeds a previously set value.

Figure 2. BMImin and BMImax thresholds for each French department - 2011 values
(from Météo-France)



Finally, in some departments, feedback from system operation was used to adjust the thresholds or reference stations, when the station was not representative of the department. This type of adjustment is done by Météo-France. Also in Marseille, the thresholds were reassessed to higher values (24-35°C compared to 22-34°C) in 2009, given the high number of alerts generated between 2004 and 2009, the low visible impact on health data, and the assumption that the city is better adapted to heat, particularly as a result of the tragic experience of 1983 [11].

3.2. Proposed alerts

The feedback from the first few years of operation and the external HHWWS assessment showed that, despite the existence of alert criteria and an operating procedure, the proposed alerts could vary from one operator to another for otherwise identical situations. It was decided to set up a tool to support decision making for harmonizing the criteria considered when deciding to raise the alert: forecasts and thresholds of biometeorological indicators, uncertainty in these forecasts, factors that could aggravate the health impact of a heatwave (heat intensity, high air humidity, air pollution, gatherings of people, etc.) and health impact once the heatwave has already set in.

3.2.1. The uncertainty associated with forecasts

In order to take into account the uncertainty of weather forecasts, the probabilities of exceeding the thresholds have been established by Météo-France for each reference city, based on an analysis of the meteorological situation and of past errors. These probabilities are translated into five categories: almost zero, low, medium, high and very high. The combination of probabilities of exceeding the thresholds for

BMImin and BMImax resulted in the creation of a meteorological score ranging from A (very low risk) to E (very high risk) (Table 1). These rules were established based on experience gained since 2004 and on the expertise of Météo-France. Greater weight was given to the probability of exceeding the BMImin threshold because of the high impact of night temperature on mortality. If the temperature is very high not only during the day, but this heat does not decrease sufficiently during the night, the body cannot recover and the health risk is increased.

Table 1 – Rules for combining probabilities of exceeding the min and max BMI thresholds (Pmin and Pmax): risk of heatwave ranging from A (very low) to E (very high)

Pmin \ Pmax	Almost zero	Low	Medium	High	Very high
Almost zero	A	A	A	A	A
Low	A	B	B	B	B
Medium	A	B	C	D	D
High	A	B	D	E	E
Very high	B	C	E	E	E

3.2.2. Consideration of aggravating factors

During a heatwave, some factors can worsen health impacts. These were identified on the basis of literature reviews and feedback since 2004 and are:

- The intensity of the heatwave, defined as the difference between the value of the indicator and the alert threshold.
- Air pollution, especially by ozone and fine particles.
- Humidity, in the sense that moist heat is harder for the body to bear than dry heat.
- Temporary events such as large gatherings of people or holiday travel dates, which increase the population at risk.

These factors may increase the vulnerability of the population subjected to heat and complicate prevention and management efforts. Insofar as no study has been done that would make it possible to consider them quantitatively (risk threshold), they are considered in an essentially qualitative way when deciding whether to raise the alert.

Thus forecasts that meteorological alert thresholds may be marginally exceeded might not lead to an alert being proposed if no other risk factor were identified; while they could lead to an alert proposal if, in addition to the heat, a busy holiday weekend was expected with many people on the roads, requiring specific heat prevention measures. This is also the case if a peak in ozone levels is expected, adding to the heat risk.

In general, these risk factors are analyzed and taken into account either by InVS when the data are available at national level (humidity, heat intensity) or by the departmental prefects when the data are produced locally (air pollution readings provided by regional associations for measuring air quality, local gatherings of people during major events such as festivals).

4. Use of health indicators during the alert

The HHWWS provides InVS with the necessary information for proposing alerts, sent in the form of a "national alert sheet" to the French General Directorate of Health (DGS).

The purpose of this alert sheet is to provide the DGS and prefects with the necessary information in order to:

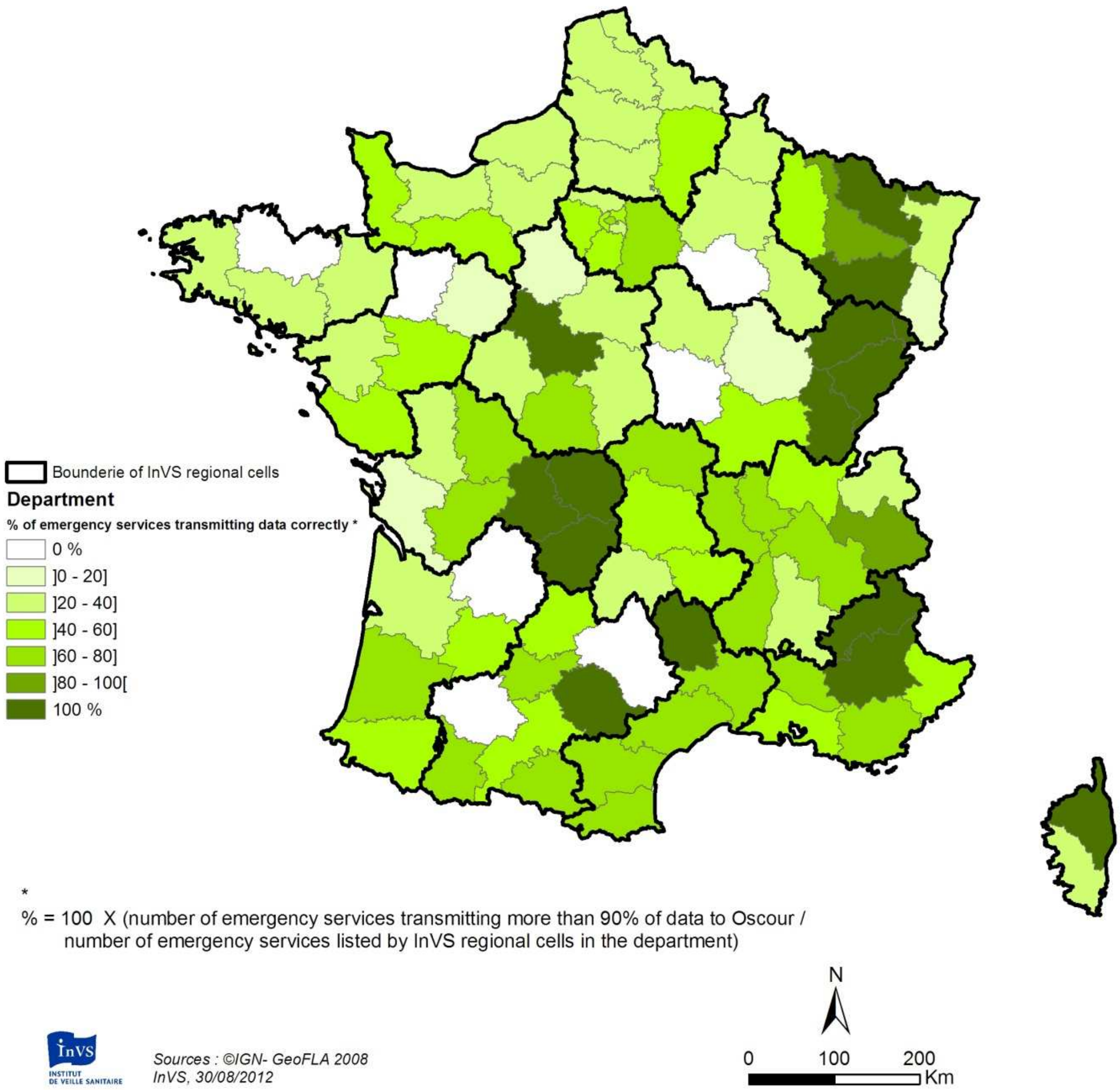
- activate the alert locally, which corresponds to the Miga level of the NHP (alert and response);
- define the scale of action;
- if an alert is in progress, propose that the alert be maintained or lifted.

For the latter two objectives, a description of the health situation in the affected departments is useful. It has been produced by the InVS Regional Cells (Cire) since 2004 based on mortality and morbidity data collected in a sample of sentinel cities (at least one city per department in mainland France). Since 2011, the indicators used are [12]:

- ➢ The number of deaths recorded by the civil registries: although it is not very reactive (it takes about 7 days to produce consolidated data), it is important to monitor this indicator while remaining aware of its limits, because in 2003 a large proportion of deaths occurred in people's homes, before reaching hospital. It would therefore be risky to monitor only indicators relating to use of healthcare resources, which might show only slight changes even when the situation is catastrophic. These data are collected via the Insee server.
- ➢ Total emergency hospital admittances, for persons over 75 and for conditions resulting specifically from heat (hyperthermia, hyponatraemia and dehydration). These data are collected through the regional monitoring and early warning servers (SRVA) or the Oscour® device (Organization of the coordinated monitoring of emergencies). Mostly represented by facilities in the Paris region at the beginning, its geographical coverage has expanded gradually and progressively allows automated data feedback for a large number of departments (Figure 3).
- ➢ Calls to the SOS Médecins services, available since 2006, are used to collect general practice consultation data, in terms of subjective patient experience (reason for call) and, for certain geographical areas, in terms of pathology diagnosed by the doctor during the visit. During the summer, calls by age bracket are particularly interesting as elderly people rarely use this service, except when their health condition becomes particularly concerning. These data are also collected via the Oscour® device in areas where they are available.
- ➢ Other indicators can be monitored in each department depending on data availability:
    - Data from funerals, when these are sufficiently complete and interpretable.
    - The cases handled by the Samu (number of "medical regulation files" = all the information collected, measures taken and monitoring undertaken, as a result of medical, medico-social or health information brought to the attention of the Samu –15 Call centre).
    - The cases handled by fire-fighters (departmental fire and rescue services) at the request of Samu, hence for medical problems.

These indicators were selected based on three essential criteria: proven link to heat, responsiveness and quality of data.

Figure 3. Emergency Reception Services (SAU) transmitting their data to InVS via the Oscour system in August 2012. The data are represented by department based on the percentage of establishments regularly transmitting data in accordance with the required standards.



Two statistical methods were selected to analyze these indicators from the available data. They are based on methods for detecting unusual events (statistical alerts):

- The historical limits method, if the data necessary for the calculation are available (at least 2 years of history).
- The control charts method, which does not require historical data.

These statistical alerts must be validated by an epidemiologist before being considered as health alerts.

At the end of a heatwave, when the biometeorological indicators no longer show a high risk of exceeding the thresholds, and there is no validated alert on the health indicators, a proposal will be made to lift the Miga level of the heatwave plan.

However, a health alert may lead to the Miga level being maintained and the NHP measures being adjusted accordingly.
Moreover, when the BMIs are close to the thresholds, an alert on the health indicators could lead to a heatwave alert being proposed.

5. Post-alert health outcomes

Beyond monitoring the health impact in real time, it is important to quantify the health impact of the heatwave once the alert is over, by working on validated data.

The literature indicates that heatwaves have a significant impact on mortality, although few studies have examined morbidity. Total excess mortality is considered a good indicator of the impact of heatwaves, since diseases specifically related to heat (hyperthermia, dehydration) constitute only a portion of the total impact, and are often under-reported [13].

The indicator used was therefore mortality, and a simple method was defined to estimate the impact of a heatwave. Thus, excess mortality during the study period (period during which biometeorological thresholds were reached or exceeded) is defined as the difference between observed mortality and a reference mortality rate. This reference mortality rate is calculated as the mean of observed mortality over the same period for the previous N years (N ranging from 1 to 5), excluding the data from any heatwaves. This provides an estimate of the impact according to several reference periods. A comparison with the results obtained by a time series model has confirmed the utility of this simple method for obtaining a quick estimate of the scale of the impact. When an impact is observed, further analysis can be conducted, including the use of time series modelling, taking into account more accurately the effect of extreme temperatures [14].

With regard to morbidity, beyond the descriptive analyses that can be conducted using the previous indicators, it seems important to develop a better understanding of the morbidity–temperature relationship in order to establish a standardized impact indicator. It will therefore be necessary to conduct a review of the literature on the subject and subsequently, to test different methods on our morbidity indicators (e.g. time series), as soon as data become available in sufficient quantity and quality.

6. Assessment and adjustments

Inserm has developed a model to estimate excess mortality related to temperature (throughout France). This model was built over the years 1975-2003. During the heatwave of 11th to 28th July 2006, 2065 excess deaths were observed. According to the model [15], the recorded temperatures should have resulted in excess mortality of 6452 deaths. The actual figure was thus 4387 less than the expected total. This "lack of excess mortality" may be considered as a reduction in the vulnerability of the population to heatwaves, attributable to increased awareness in the population to the dangers of heat since 2003, the implementation of a warning system and the measures of the heatwave plan. It is not, however, possible to confirm that the current device cannot be improved to further increase the health impact. Moreover, the HHWWS is subjected to regular internal and, less frequently, external assessments.

6.1. Assessments of the warning system

Externally, the HHWWS has been assessed twice, in 2004 and 2005 by a research firm, which examined its scientific foundations, functional qualities, performance and cost.

Internally, the InVS/Météo-France workgroup regularly reviews the meteorological alert thresholds, use of forecasts and relevance of reference weather stations. In 2009-2010, a system assessment was conducted more specifically to review the meteorological alert thresholds and health indicators used to monitor the impact of heat (during an alert and at the end of the summer): choice of relevant mortality and morbidity indicators and statistical analysis methods for these indicators. At the end of each summer season, a logistical, scientific and information technology review is conducted by the national InVS and the Regional InVS Cells (Cire). It is used to determine the strengths and weaknesses of the system and to draw up the health outcomes of a heatwave, with the aim of implementing improvements for the following summer.

6.2. International comparisons

It should be noted that when the HHWWS was developed, there was little existing knowledge on heatwave warning systems. An international workshop organized in 2005 by the InVS provided the opportunity to compare the French HHWWS with its international counterparts and to identify some areas for improvement.

Since then, the different systems existing in Europe have been surveyed by the Euroheat project [16], with the conclusion that there was no "reference method" for designing such systems.

A comparison of four types of warning system (synoptic in the U.S., mean temperatures in France, perceived temperature in Germany, Humidex in Canada) with the same data sets (Chicago, Montreal, Madrid and London) revealed that there was little consistency between the days considered as high-risk by the different systems, and that overall the French HHWWS produced good results [17]. This study is not an assessment, but confirms that the French HHWWS indicators are effective in identifying days associated with high excess mortality.

6.3. NHP monitoring

Assessment of the warning system is one part of the NHP assessment carried out each year by the French Interministerial Heatwave Committee (Cica), which principally examines implemented efforts: for instance, implementation of cooled rooms in retirement homes was rapidly estimated at almost 100% while this figure could still be improved in hospitals. Moreover, the NHP recommendations for protecting oneself from the heat and protecting vulnerable people seem to be followed by the large majority of French people aged over 15, according to a study by the National Health Education and Prevention Institute (Inpes) [18].

The annual Cica meetings enable to report problems encountered in the field, and sometimes the need to conduct assessments.
Thus, with regard to practices in retirement homes, in 2009 the Minister of Health set up the National agency for supporting the performance of healthcare, medical and social institutions (Anap), charged with reporting on what has been done and assessed in relation to heatwaves. This project has not yet been implemented.

With regard to prevention messages, Inpes regularly reports on updates and the quality of their relay by the media and entities through which they are transmitted, but there is no information on their use locally. With regard to the Météo-France vigilance map, a survey by the French Research centre for the study and observation of living conditions (Credoc) revealed that a great number of French people know this map, but without the details about heatwave messages. It would be interesting to carry out surveys to know which measures are known and used by people during a heatwave, particularly by elderly persons who are the most vulnerable, but also by outdoor workers.

The measures for which local authorities are responsible include the creation of a list of people with disabilities and elderly people, which is mandatory for towns with over 5,000 inhabitants. However, it is difficult to obtain precise information on implementation of this mechanism (number of people included in the lists, implementation of measures by town halls or by delegation to the associations that are required to make contact with the people on the lists and assist them if necessary). Regional Health Agencies also have lists of people who are sick and at risk of death (specifically in the event of power cuts: dialysis, respiratory assistance, etc.) and the Samu has a list of noteworthy patients identified from calls to the switchboard. Nevertheless, assistance for people who are most vulnerable via the municipal lists remains a point for investigation and no doubt, improvement.

With regard to application of the measures in the NHP by prefects during an alert, we have only very incomplete information, about a certain degree of reticence among prefects to trigger the Miga level, either due to administrative complications, or to a lack of knowledge of the fact that it does not entail systematic implementation of all measures in the plan, but only those that seem appropriate to the situation. These points would benefit from being investigated further through studies in the field.

6.4. Possible changes to the warning system

With regard to the warning system, an assessment of the meteorological thresholds and health indicators was conducted in 2009. However, only one significant heatwave has occurred since August 2003, in July 2006, in addition to two episodes of low importance in a small number of departments, in July 2010 and August 2011. The August 2012 heatwave has just occurred and has not yet been investigated at the time of this report edition. It is still too soon to assess whether the impact of heatwaves on mortality and morbidity has changed since implementation of the HHWWS, although standardized methods are starting to be set up for this purpose, and will provide some answers. Moreover, while meteorological and mortality data are available for several years, the morbidity data history is still sparse despite progressive implementation of the Sursaud® information system, which currently collates data from SOS Médecins and hospital emergency services.

Since the effectiveness of a warning system depends partially on its acceptability, it does not seem relevant to look for new meteorological indicators to replace the HHWWS indicators, which are already well understood by the various actors of the system. Moreover, different indicators were already tested in 2004 when the warning system was being set up, and gave less relevant results than the indicator based on minimum and maximum temperatures. Neither is the literature conclusive on the subject of a meteorological indicator more sensitive than temperature for characterizing the impact of a heatwave on health. Specifically, the inclusion of humidity in temperature–mortality models does not provide any specific benefits, whether in the form of an independent variable or a mixed temperature-humidity indicator such as apparent temperature [19]. But probable changes in the characteristics of future heatwaves, specifically increased humidity (http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch3s3-4-2-1.html), could lead to modifications to the warning system.

The concepts of sensitivity and specificity were introduced in the HHWWS to help choose indicators. These concepts are traditionally applied to clinical tests, for which the events are reproducible. However, future heatwaves will no doubt differ from previous heatwaves, both in terms of their specific meteorological characteristics and their potential impact linked to changes in lifestyle or demographic changes resulting in increased vulnerability of the population. The indications given by sensitivity and specificity should therefore be interpreted with caution and are a simple indication of the retrospective performance of the system. They cannot be used to judge its future performance.

Eleven of the 12 years in the period 1995-2006 are included in the hottest 12 years since 1850. In the future, due to climate change, the thresholds will probably be exceeded more frequently, which could result in more frequent proposed alerts. Thus, without a reduction in greenhouse gases, the number of days with temperatures over 30°C in France could equal current figures observed in Spain or Sicily [20].

The health impacts of future heatwaves will not necessarily be the same as in the past: an identical event, of the same intensity, at the same period of the year in the same place as a past event, may have different consequences, depending on changes that take place in society, specifically:

- Changes to the healthcare system.
- Adaptation to heat through technical means [21]: air conditioning, improved ventilation of buildings (Canadian wells, etc.), improved insulation of buildings, high-reflective coatings, modification of the urban environment (green spaces, adapted urban forms).
- Behaviour changes with regard to heat. It may be necessary to raise the thresholds if the population adapts to heat. However, while physiological adaptation has been witnessed in people in good health after appropriate heat training, this is not possible for the elderly, who are the most vulnerable to heat. Studies have also shown that the impact of temperature on mortality dropped between the 50s and the 90s, probably due to technological, structural and biological adaptations. However, more heatwaves would have been required to verify whether this reduction in vulnerability has continued in recent years.
- Increasing urbanization, given that mortality is greater in large built-up areas than in rural areas, particularly due to urban heat islands [22]. Global warming, specially the rise in night temperatures, could lead to a twofold rise in mortality attributable to heat in less than 20 years in large urban areas [23].
- New demographic trends: population growth, especially the proportion of elderly people, who are the most vulnerable. In 2003, people aged over 75 accounted for 8.8% of the French population, and this figure could rise to 15.6% by 2050 according to Insee projections (http://www.insee.fr/fr/themes/document.asp?ref_id=ip1089).

Thus, the question of population adaptation cannot easily be solved but will require further research to document efforts that have already been implemented and their impact on the temperature-mortality relationship.

In conclusion, although the analysis of the July 2006 heatwave health impact revealed a lower excess mortality rate than expected, it remains necessary to continue prevention strategies, adapting them to those population groups most affected by heat. The improvement of the HHWWS to optimize decision making and better assess the health impact, via the surveillance of health indicators, is a step in this direction, but it cannot be dissociated from long-term, continual assessment and improvement of the measures implemented in the event of an alert.

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The French Heat and Health Watch Warning System: principles, fundamentals and assessment

The Heat and Health Watch Warning System (HHWWS) was implemented at the beginning of summer 2004. It is based on forecasts of biometeorological indicators for heatwave alerts that activate a defined answer in the framework of the National Heatwave Plan. A syndromic surveillance system enables to follow at day+1 the possible health impact of a heatwave.
Throughout the years, the HHWWS has been assessed inside our Institute and by exterior organizations. Logistical and scientific improvements were brought.
This report presents the principles of the HHWWS, the main steps of its implementation and assessment, and it summarizes the meteorological and health indicators followed from 2004 to 2012.
The limits and perspectives of the system are mentioned, in particular the possibilities of evolution in the framework of climate change, demographical, public health and health care system changes, as well as changes in people behaviour since the 2003 heatwave and the setting up of the National Plan for heatwaves.

Key words: Heatwave – alert system – meteorological indicators – health surveillance – assessment

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