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ORIGINAL ARTICLE

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France's heat health watch warning system

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Abstract In 2003, a Heat Health Watch Warning System was developed in France to anticipate heat waves that may result in a large excess of mortality. The system was developed on the basis of a retrospective analysis of mortality and meteorological data in fourteen pilot cities. Several meteorological indicators were tested in relation to levels of excess mortality. Computations of sensibility and specificity were used to choose the meteorological indicators and the cut-offs. An indicator that mixes minimum and maximum temperatures was chosen. The cut-offs were set in order to anticipate events resulting in an excess mortality above 100% in the smallest cities and above 50% in Paris, Lyon, Marseille and Lille. The system was extended nationwide using the 98th percentile of the distribution of minimum and maximum temperatures. A national action plan was set up, using this watch warning system. It was activated on 1st June 2004 on a national scale. The system implies a close cooperation between the French Weather Bureau (Météo France), the National Institute of Health Surveillance (InVS) and the Ministry of Health. The system is supported by a panel of preventive actions, to prevent the sanitary impact of heat waves.

Keywords Heat Health Watch Warning System · Temperature · Mortality · Heat wave

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Introduction

Extreme summer temperatures are known to be associated with increased daily mortality in temperate regions (Applegate et al. 1981; Basu and Samet 2002; Benbow 1997; Besancenot 2002; Diaz et al. 2002a,b; Donaldson et al. 2003; Hajat et al. 2002; Jones et al.1982; Katsouyanni et al.1988; Marmor 1975; Rooney et al. 1998; Sartor et al. 1995; Thirion 1992, WHO Regional Committee for Europe 2003). However, in France the population and the health authorities were not prepared to face the unusual heat wave that affected the country in August 2003, resulting in an estimated excess mortality close to 15,000 deaths between the 1st and the 20th of August 2003 (Hémon and Jougla 2003). Summer 2003 was indeed the hottest ever recorded in France. Should the actual theories about global warming be verified, similar meteorological events may increase in intensity and frequency (WHO 2003). Over the last 30 years, the annual number of warm extremes (minimum and maximum temperatures) has already increased more than expected, the minimum (night-time) temperatures increasing more strongly than the maximum (day-time) temperatures (WHO 2003).

There is no standardized definition of a heat wave. The existing definitions generally refer to a definite period of time during which the air temperature is above a threshold (Robinson 2000). This threshold varies geographically. Indeed, the vulnerability of the population depends on the local climate, and the sanitary impact of heat waves seems to be higher in cold and temperate regions. For instance, the biological threshold ranges from 41°C in Andalusia (Diaz et al. 2002a,b) to 27.5°C in Belgium (Sartor et al. 1995). In France, a previous study focusing on the Mediterranean regions proposed to identify a heat wave when the mean temperature exceeded 25.9°C in Marseille and 28.2°C in Avignon (Doucoure 1993). In this case, a difference of 2.3°C is observed between cities that are only about 100 km apart.

Elevated temperatures may have direct and indirect consequences on human health. Direct consequences range from heat cramps and heat exhaustion with dehydration to severe heat strokes and death. Heat strokes can occur less than 24 hours after the exposure to high temperatures. Elevated temperatures may also exacerbate chronic illnesses, including cardiovascular diseases or respiratory diseases (Auger and Kosatsky 2002; Hajat et al. 2002; InVS 2003; Kunst 1996; Rogers and Williams 2000; Besancenot 1990a). The lag time between heat exposure and indirect health effects depends on pre-existing diseases. Several studies have shown that the epidemic peak of mortality is reached from one to two days after the hottest day of the heat wave (Applegate et al. 1981; Braga et al. 2002; Laaidi et al. 2002, 2003; Smoyer 1998). The literature reports that several methods have been used to investigate the relationship between heat load and mortality, including descriptive studies of heat waves, time-series analysis, case-control studies and case-cross over studies (WHO 2003; Basu and Samet 2002; Rooney et al. 1998; Changnon et al. 1996; Cooter 1993; Jones 1993; Kalkstein et al. 1996; Kirk 1996; Kunkel et al. 1996; Kunst 1996; Semenza et al. 1996). In most of these studies, the air temperature is taken as a simple measure to describe heat load. The relationships between temperature and mortality are generally U- or V-shaped, and threshold temperatures at which mortality is lowest have been determined in temperate zones. However, heat waves, i.e. prolonged periods of elevated temperatures, may have larger impacts on mortality than expected from the results of the time-series analysis, as they refer to exceptional events. Specific analyses are then required when focusing on heat waves.

World-wide, current Heat Health Watch Warning Systems (HHWWS) have been developed for individual cities (Kalkstein et al. 1996, Kalkstein 2002, WHO 2003). Although they can strongly differ in the method, they still have basic common points: a reliable meteorological forecast, a good understanding of the relationship between heat load and health, and effective action plans (WHO 2003). In Western Europe, Rome (Italy) and Lisbon (Portugal) were the only cities to run an effective HHWWS in 2003. In Rome, a system from WHO/WMO/UNEP Showcase Projects was used, which was then also applied in several other Italian cities within the European project PHEWE (Assessment and Prevention of Acute Health Effects of Weather Conditions in Europe). It is a synoptic approach that associates adverse effects on mortality with the type of air mass (Kalkstein 2002; Michelozzi et al.2004). In Lisbon the ICARO system was used, based upon three-hourly mean temperatures.

Following the terrible 2003 heat wave, the French government decided to develop a HHWWS to anticipate heat waves that may result in a large excess of mortality. The objective of the HHWWS is to alert the authorities in time to allow the set up of preventive actions. This project began in January 2004 and was delivered to the authorities in May 2004. It had to be efficient for the whole country, i.e. with several thresholds adapted to the local sub-climates. After a preliminary review of existing systems, the choice was made to apply a descriptive data analysis to find a meteorological indicator that shows a clear relationship with excess mortality. That indicator had to be associated with a bio-meteorological threshold, able to separate the days when the mortality is above the action-level and the days when it is below that level. The cut-offs had to be in accordance with the recommendations of the Ministry of Health, i.e. preventing a big epidemic event.

The driving reasons for selecting this method were practical, since the task was to create a whole system as soon as possible with limited time and resources. Hence, a simple but robust method was chosen, as the authors believes that the successful application of more complex methods in so short a time would not have allowed a complete understanding of the problematic and the correct handling of all the hypotheses. This seems especially true for the air masses approach, which requires a specific competence in meteorology. Moreover, as the aim of the system is to detect large events, a complex model would not be so useful (advanced models are useful to detect smaller events that this system is not able to recognise).

The choice of the meteorological indicators may also appear rough. Indeed, several parameters are relevant to understand a heatwave and should be considered to explain the heat load supported by the body and susceptible to create adverse effects. Yet, when the objectives are not to explain the influence of heat waves on health but to identify days that are potentially at risk, a simpler approach is relevant.

The HHWWS is integrated in the four levels of the national action plan, as:

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

The system became active on 1st June 2004 on a national scale and stopped on 1st October 2004. The period of activation, from June to September, was defined by the stakeholders.

Materials and methods

Period and area of study

The adaptation and vulnerability of the population to heat waves depend on the local average temperatures and on the frequency of heat waves (Donaldson et al. 2003). Several studies have found that the relationship between elevated temperature and mortality had a significant spatial component from oceanic to continental areas and from countryside to urban areas (Besancenot 2002; Chestnut et al. 1998). Thus, it was decided to work on a panel of pilot cities representative of the variety of climates that are to be found in France: Bordeaux, Dijon, Grenoble, Le Havre, Lille, Limoges, Lyon, Marseille, Nantes, Nice, Paris and its suburbs, Strasbourg, Toulouse and Tours. Figure 1 shows the location of these cities together with the regional repartition of excess mortality in August 2003.

Data were collected for the period 1970 – 2003 and the analysis focused on summertime, between the 1st of June and the 31st of August. This period was chosen as the warmest period of the year. Before June and after August, night temperatures are low enough to prevent large sanitary effects.

Meteorological data

Deadly heat waves have always been associated with elevated night-time temperatures (Besancenot 1990a; Diaz et al. 2002a,b). In July 1983, the South of France experienced a severe heat wave with daily temperatures exceeding 42°C in some places. However, an excess of mortality was observed only when the night-time temperature was above 20°C in a restricted area (Besancenot 1990b; Simonet 1985). The minimum, maximum and mean temperatures were hence collected as pertinent indicators of the potential impact of the heat wave. The difference between the current day temperature and the 30 year-period normal (Tdif) was computed, and a mixed indicator was built as a logical combination of minimum (Tmin) and maximum temperatures (Tmax).

Since the mechanisms regulating the body core temperature are compromised when the vapour pressure of the atmosphere increases (WHO 2003), additional focus has been put on indicators combining temperature and the humidity rate of the atmosphere, such as dew point temperature (Tdp), humidex, apparent temperature, and the thermo-hygrometric index (THI) (Laaidi 1997; Besancenot 1990b, 2001; WHO 2003; Basu and Samet 2002). During heat waves, a high correlation (>0.98, $p<0.05$) was found between the apparent temperature, the humidex and the thermo-hygrometric index, so only the latter was used for all analyses. The THI was selected for its simplicity.

Additional parameters such as wind speed or cloud cover are also known to lead to deterioration in human health. They can be integrated through an air mass approach (Kalkstein et. al. 1996) or through a heat budget approach (Jendritzky et. al. 2000). However, as this study aims at identifying simple indicators, these two approaches were not tested.

Meteorological data were obtained from the French Weather Bureau, Météo France.

Mortality data

The relationship between meteorological indicators and daily excess mortality is highly sensitive to the method used to estimate the excess mortality. The daily mortality baseline was computed as a moving average over the three preceding years of daily mortality, The daily mortality was

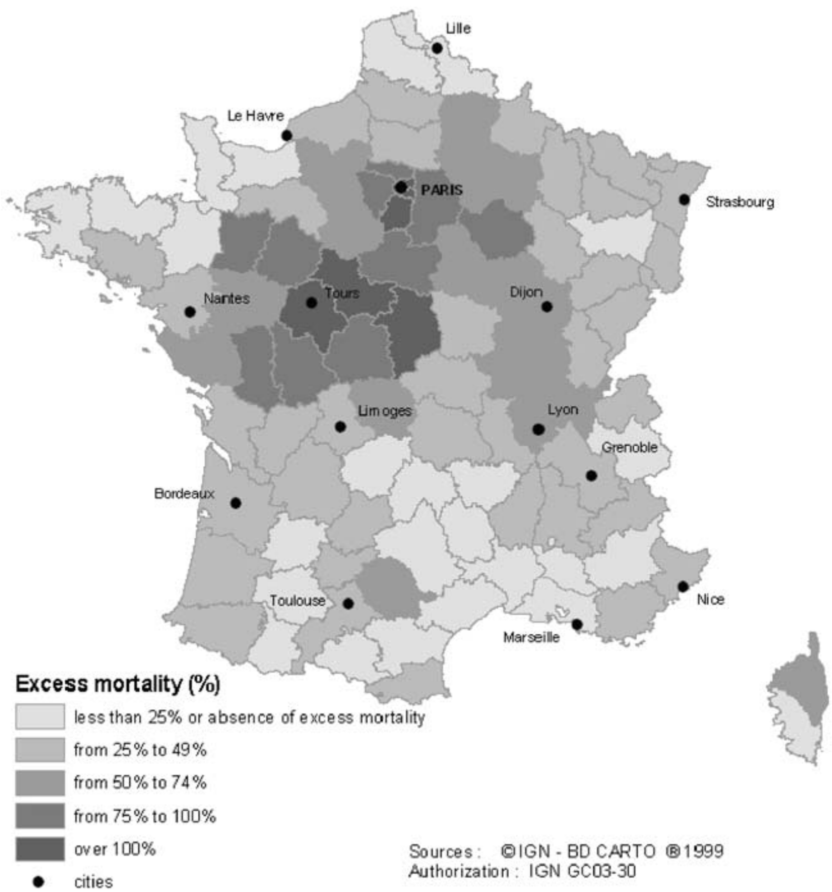

Fig. 1 Distribution of the pilot cities, and excess mortality observed in August 2003

defined either as the mortality observed on the actual day, or as the mean of the n previous and n following days (n=3, 7 or 15).

All causes - all ages daily mortality data were obtained from the National Institute of Statistic and Economic Studies (INSEE: Institut National de la Statistique et des Études Économiques).

Methods

Meteorological indicators

In a first step, different meteorological descriptors were tested on a daily basis. 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. A sensibility (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. Receiver Operating Characteristic (ROC) curves were used to visualise the sensibility (Se) and the specificity (Sp) of the system.

Different meteorological thresholds have been tested for each indicator in relation to different excess mortality thresholds. The method was an iterative one; daily meteorological data that coincide with an excess mortality above the action level were used to compute an initial meteorological threshold, as the minima of these values. It represented the meteorological threshold with the highest sensitivity but also with the lowest specificity. From this initial value, the threshold was implemented per 1°C-step. For each new threshold Se, Sp, PPV and NPV were computed. It has to be stressed that the thresholds are constant over the period, while they could have been defined, for instance, on a daily basis. However, it is believed that the seasonal variability of the threshold is not predominant in this study, as it focused on extreme events.

To deal with the high variability of the daily mortality, the low number of deaths in most of the cities, and to include the notion of duration, the same computations were also done on a three-day period basis, the mortality data being summed over three days and the meteorological data being averaged on the same period. ROC curves were used to choose between a system based on daily or on three-day period data. Lags of 1 and 2 days between temperature and mortality were also considered in this study.

The thresholds have then been discussed in close collaboration with the stakeholders. The aim of the health authorities was to limit the number of missed alerts (to maximize the sensibility) and to reduce the number of false alerts (to maximize the PPV and the specificity). As these two objectives are in opposition, the decisive criterion was the sensibility.

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. A first method was to extend the threshold of a city to its climatic region, defining homogeneous thermal regions for minimum and maximum temperatures. Another method was to express the thresholds in terms of their difference from the 30-year normal temperatures. The last method was to focus on the percentiles of the meteorological indicators (Hajat et al. 2002). Se, Sp et 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 HHWWS without being pilot cities (a total of 82 cities).

Sanitary indicators

The meteorological indicators were used to build a watch-warning system able to detect a potentially threatening heat wave within three days. In parallel, a real-time system was designed that uses health data collected on a daily basis. These data include the number of deaths, the number of hospitalizations, the number of emergency interventions and the activity of funeral homes. In three regions (where there is enough staff), these data are collected daily and analyzed during the summer. All the other regions collect the data only when the meteorological watch-warning system has pointed out a risk of heat wave. This daily health data system is useful to decide if the situation is normal or if actions should be pursued even after the end of the heat wave.

Results

Meteorological characteristics of the pilot cities

In all cities, daily seasonal temperatures (daily mean over 30 years) increased from the 1st of June to the second week of August before decreasing. Lille had the lowest seasonal minimum (12.5°C) and maximum (21.2°C) temperatures of the 14 cities. The city of Nice had the highest minimum (19°C) and Marseille the highest maximum (28.5°C).

Heat waves

Heat waves were always characterised by a steep increase of maximum and minimum temperatures and duration of several days. The largest heat waves - in 1976, 1983 and 2003 - lasted at least 10 consecutive days (Fig. 2). All heat waves lasting several days have been associated with an increase in mortality that is still observable when compar-

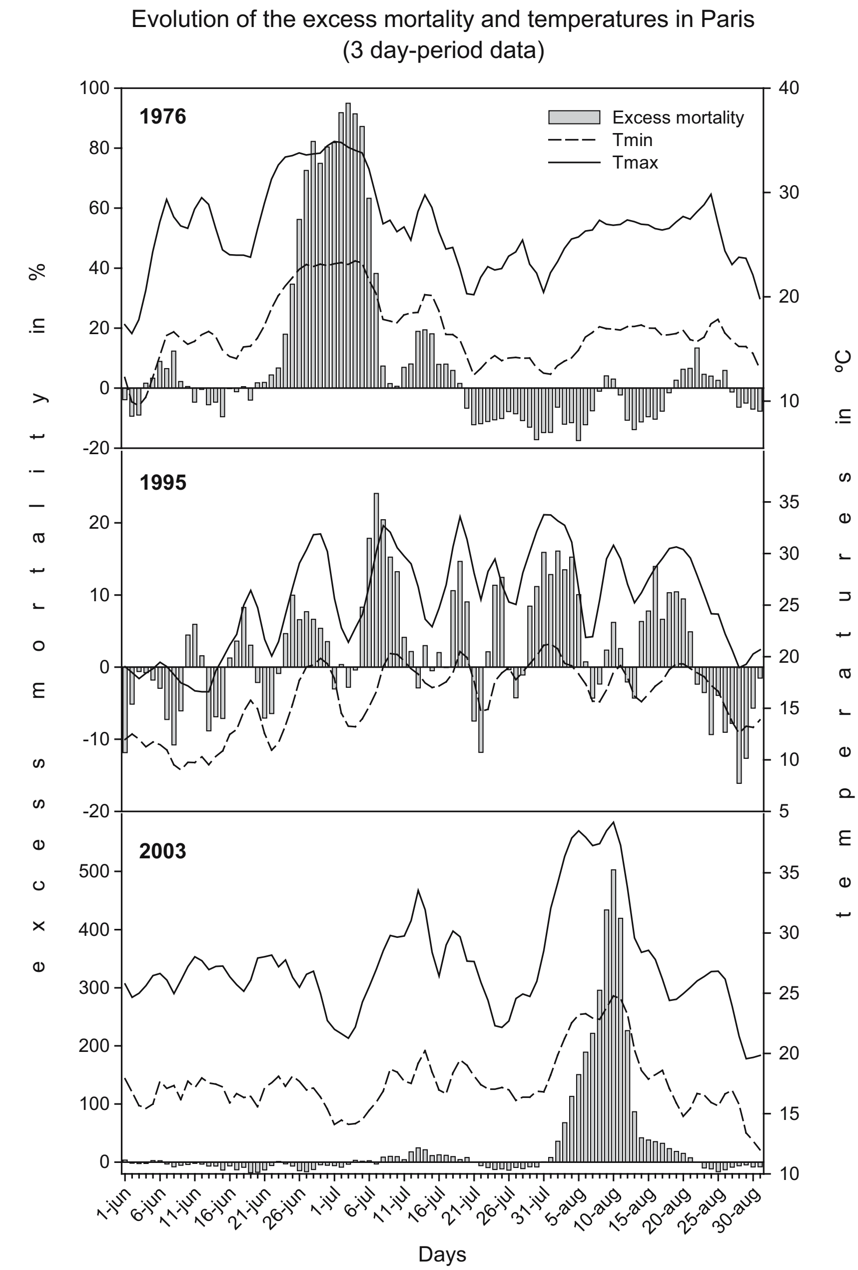

Fig. 2 Major heat-waves in Paris

ing the mortality of the month associated with the heat wave to its reference baseline, as shown in Table 1.

Mortality baseline

Of all cities, Paris has the highest daily number of deaths (185 per day in average for Paris and its suburbs) while Dijon has the lowest daily number of deaths (4.2 per day on average). In Paris, Marseille, Lyon and Lille, the excess mortality exceeds 50% and 100% mostly during heat waves. In the other cities, the threshold of 50% is frequently reached, without any clear link with temperature.

The use of different smoothing windows had little impact on the sensitivity and specificity of the test. In all cases, the mortality summed over three days clearly showed better results and was chosen as the reference mortality. It strongly increases both the sensibility and the specificity (Fig. 3).

Biometeorological indicators

A qualitative summary of the performance of each indicator is reported in Table 2. The selection of the indicator was based on the shape of the ROC curve. ROC curves showed that the dew point temperature was not an appropriate indicator. Maximum temperature, mean temperature and thermo-hygrometric index showed similar performance. However, in France heat waves have always been characterised by rather dry conditions, so that the THI was mainly equivalent to the mean air temperature. Minimum temperature performed slightly worse. The temperature difference

Table 1 Heat waves, associated mortality and temperatures

	Heat wave dates	Mean temperatures observed during the heat wave period (°C)		Mean excess mortality (Excess mortality %) over the corresponding month
		Tmin	Tmax	
Bordeaux	5–9 August 2003	22.3	37.5	13.8 (+19%)
Dijon	5–11 August 2003	19.6	35.6	5.5 (+15%)
	22;24–25 July 1994	18.1	31.3	5.2 (+18%)
Lille	7–11 August 2003	18.8	33.2	21.3 (+8%)
	25–27 June 1976	17.7	32.8	28.3 (+12%)
Limoges	6–15 August 2003	19.3	31.2	4.5 (+19%)
Lyon	3–12 August 2003	21.8	37.6	39.5 (+56%)
	19–20;23;26;28;30 July 1983	21.3	34.9	33.9 (+25%)
	3–4 August 1975	18.8	34.2	28.2 (+6%)
Marseille	23–29 July 1983	24.1	36.4	43.7 (+25%)
Nantes	1–3 July 1976	19.9	38.9	11.8 (+27%)
	9–11 July 1983	21.8	34.0	11.1 (+10%)
	2;6–10 August 2003	20.4	35.6	13.0 (+44%)
Nice	3;8–9 August 2003	25.3	32.2	33.4 (+25%)
Paris	2–12 August 2003	22.9	36.4	308.1 (+91%)
	1–2 August 1990	22.1	34.9	187.7 (+8%)
	1–5 July 1976	22.9	33.9	244.6 (+23%)
	2–4 August 1975	21.7	33	215.9 (+11%)
Strasbourg	5–10 August 2003	18.4	37.2	11.3 (+46%)
Tours	31 July 2003	20.0	35.6	13.4 (+144%)
	1–12 August 2003			
	8–10 August 1998	16.1	30.7	6.5 (+7%)
	1–3 August 1975	18.1	33.7	5.9 (+13%)

from the seasonal average gave good results in some cities but it was not possible to find a unique value for all the French cities, defining a threshold as Tmean+X°C. Specifically, the threshold Tmean+7°C sometimes found in the literature was not satisfactory in most of our cities (Besancenot 1997, 2002).

The ability to forecast the parameters with confidence was also taken into account. Based on meteorological advice, it was stated that during heatwaves, temperatures forecast a higher confidence level and humidity a lower confidence level. The bio-meteorological indicator that showed the best performances in all cities and that was suitable for forecasting was finally the combination of the minimum and the maximum temperature above specific thresholds.

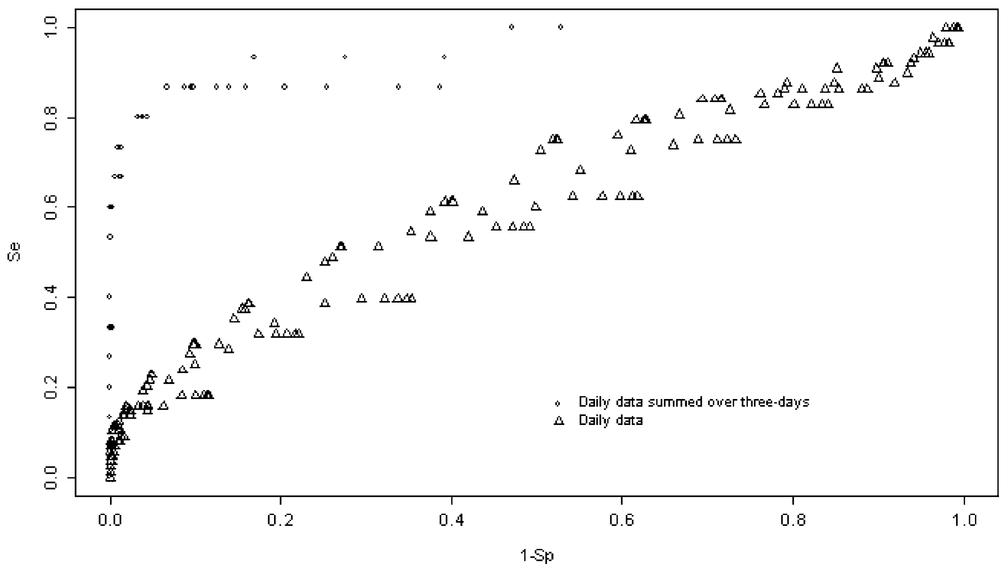

Fig. 3 ROC curve for Marseille: Sensibility and specificity of the watch warning system in Marseille when using three-day period data or daily data. Each point represents the Se and Sp computed between 1973 and 2003 for a specific cut-off

Table 2 Qualitative appreciation of the relevance of the biometeorological indicators based on ROC curves

Indicators	Performances	Suitability for forecasting
Minimal daily temperature	Medium	
Maximal daily temperature	Good	
Mean daily temperature	Good	
Difference of temperature=Mean daily temperature-Seasonal mean daily temperature	Medium	Can be used in a warning system with fair confidence (quadratic error around 2°C)
Minimal AND Maximal daily temperature	Good	
Dew point temperature	Really poor	Cannot be used in a warning system,
THI	Good	as the uncertainties on forecasting are too high

Lags

The introduction of a lag of 1 or 2 days showed no significant improvement in the sensibility and specificity of the system, with whatever indicators and mortality baselines were considered.

Methods for extending the thresholds to the whole territory

The first method was based on homogeneous thermal regions. However, thermal regions for minimum and maximum temperatures do not overlap each other and the pilot cities are not equally distributed in each of these regions. Hence, this method was not satisfactory.

The second method was based on the difference between the thresholds and the seasonal normal temperature. The main obstacle was that the range of seasonal temperatures is larger in France than in our pilot cities: from 8.1°C to 19.5°C vs. 12.5 to 19°C for the minimum temperatures and from 15.1°C to 29.7°C vs. 19.9 to 28.5°C for the maximum temperatures. The pilot cities were not representative of all these situations.

The last method, that tested the percentiles 94, 95, 96, 97, 98 and 99 as indicators, was adopted. Except for the

Table 3 Selected thresholds for the pilot cities, with their positive predictive value (PPV) and their sensitivity (Se)
For comparison, the 98th (or 95th for the biggest cities) percentile of Tmin and Tmax is given

	Thresholds		PPV for the detection of an excess mortality>100%	Se for the detection of an excess mortality>100%	98th Percentile of the distribution of temperature between 1970–2003	
	Tmin (°C)	Tmax (°C)			Tmin (°C)	Tmax (°C)
Bordeaux	22	36	0.71	1.00	21	35
Dijon	19	34	0.44	0.15	19	34
Grenoble	15	35	0.24	0.36	19	34
Limoges	16	36	0.44	0.16	20	32
Nantes	20	33	0.55	0.61	20	33
Nice	24	30	0.54	0.72	24	31
Strasbourg	17	35	0.54	0.60	19	33
Toulouse	21	38	0.11	1.00	31	36
Tours	17	34	0.56	0.52	19	34
	Thresholds		**PPV for the detection of an excess mortality>100%**	**Se for the detection of an excess mortality>100%**	**95th Percentile of the distribution of temperature between 1970–2003**	
	Tmin (°C)	Tmax (°C)			Tmin (°C)	Tmax (°C)
Lille	15	32	0.30	0.64	15	32
Lyon	20	34	0.54	0.59	20	34
Marseille	22	34	0.32	0.60	22	34
Nantes	20	33	0.55	0.61	22	33
Paris	21	31	0.66	0.96	20	32

biggest cities (Paris, Lyon and Marseille), where the 95th percentile can be associated with a 50% excess mortality, the 98th percentile gave the best results (Table 3), without decreasing the PPV. It keeps the alert system adequately sensitive. It was hence decided to extend the HHWWS to the whole country using the percentiles computed over 30 years of meteorological data including 2003.

Discussion

The final choice of a combined indicator "Tmin and Tmax" is consistent with the literature. Indeed, it has already been observed that the maximum temperature alone was not sufficient to estimate the health risk. An elevated by-night temperature not allowing the body to rest is also a key risk factor (Besancenot 2002).

Several studies have underlined the existence of a significant spatial variability in the health impact of heat waves. Continental and coastal regions showed different patterns, as well as urban areas and the countryside (Besancenot 2002; Chestnut et al. 1998). This heterogeneity has been confirmed by the thresholds we found, from 14°C to 24°C for minimum temperatures and from 28°C to 38°C for maximum temperatures.

Moreover, the meteorological indicator must be based on data easy to predict with a certain level of confidence. The French Weather Bureau, Météo-France, is able to forecast temperature up to three days in advance. Forecasting temperatures at five days are still within the acceptance level of confidence, while forecasting temperatures at six days or more is not reliable enough to support a warning system. Humidity and dew point temperature are more difficult to forecast. The choice of temperatures forecasted up to five days in advance is indeed coherent with the need of an easy efficient indicator.

As the system was built on observed data and is to be run on forecasted data, it was necessary to test its performances with forecast data. A pre-simulation was done in Paris, Strasbourg, Nantes, Tours, Dijon, Lyon, Bordeaux, Marseille and Nice using the archives of forecasting data provided by Météo-France. In summer 2003, the simulation revealed that level 2 would have been activated in some cities during the first days of June and in July (1 to 5 days per city). Level 3 would have been activated between 10 to 33 days per city, mostly between the 3 and the 15th of August, and probably classified as level 4 in most of the cases during August 2003. Between 1st June and 1st July 2004, a level 3 alert was activated for the South of France. However, it happened to be a false positive alert, as the meteorological forecasts were higher than the real observed temperatures. Additional information such as the duration of the heat-wave, its intensity, and forecasted air pollution were used to give a general appreciation of each alert and to orient the actions.

A previous study on the 1983 heat wave in Marseille had developed threshold values based on a statistical modelling of mortality and temperature, including a lag time of one and two days. Based on this analysis, the author suggested alerting the authorities when the minimum, mean and/or maximum temperature exceeds respectively 21.3, 25.9, and 31.3°C on at least two consecutive days (Doucoure 1993). Another study, whose methodology is not indicated, gives another threshold which consists of a maximum temperature above 35°C after a night when the temperature was equal to or above 22°C, such conditions lasting at least two days (Simonet 1985). Our thresholds in Marseille are respectively 34°C and 22°C, not significantly different considering the uncertainties on the temperature forecasts. We obtained several false positive alerts in 2003 (i.e. temperatures above the thresholds while the excess mortality did not exceed 50%) that may be explained by the set up of an Action Plan in Marseille, after the 1983 event, and the lingering memory of a preventive attitude within the population and health care people. Globally, the sensibility and PPV are higher in Bordeaux and Paris and lower in Dijon and Limoges. However, the cost of a false positive alert must be evaluated by its health implications. When the excess mortality reaches 60% or more, we can consider that the activation of the action plan is not totally unjustified.

A key limitation of an approach based on excess mortality is its application to cities with low levels of daily mortality. Mortality is assumed to follow a Poisson distribution, after being adjusted for external factors such as season, epidemics, and temperature. Even if we consider that the Poisson distribution is appropriate, then 95% of daily values will fall approximately below the daily mean plus 1.64 times the square root of that daily mean. If the daily mean is 4, then 95% of daily values will be below 8, which is equivalent to our threshold of 100%. In a large city, if daily mean mortality is 100, a 50% increase in mortality corresponds to a probability of 0.000002. Thus if we encounter such increase, it will be easily linked to an external factor, unlike in a small city in which mortality levels are twice the mean on 5% of all days.

Despite the uncertainties on its future performance, this system was developed rapidly to allow the country to prepare itself for summer 2004. 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. All these possibilities will be studied for summer 2005, with a special focus on the synoptic approach and the use of time-series analysis methods. The functional organisation of the HHWWS will be fully evaluated and consequently improved for 2005 in close cooperation with meteorological experts.

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Modifications of the system for summer 2005

The experience of the first year of running of the system has lead to several changes in its design. Among these adjustments, the definition of the warning thresholds for the biometeorological indicators was slightly modified. Other modifications were done regarding the practical organisation of the system and especially the management of situations at-risk.

In 2005, the thresholds have been re-defined for two reasons. First, the use of the 98th percentile of temperature was not consistent with the use of a temperature averaged over three days. The thresholds have to be based on the distribution of moving average of temperature over three days. Second, it was assumed that the method used to define the thresholds was not applicable unless specific conditions were met. These conditions are a sufficient number of heat waves (>5) and a baseline of mortality stable enough (i.e. main cities only). Pilot cities that did not meet these criteria were then excluded from the study: Bordeaux, Toulouse and Nice because they had too few heat waves; Grenoble, Lille, Limoges, Dijon because the mortality baseline was too noisy (here the choice was qualitative). Using the remaining cities, new percentiles, based on the distribution of the averaged temperatures were computed and tested. The 99.5th percentile was chosen for its optimal combining of sensitivity and specificity. Yet, it has to be underlined that these notions of sensitivity and specificity are not readily applicable to this topic, since heat waves are not reproducible events. They only give indications on the capability of the thresholds, but the final choice is mainly subjective.

Using the 99.5th percentile new thresholds were proposed, as shown in Table 1. In most cities, the difference with the previous thresholds is lower than 1°C, expect in Lille, Grenoble and Limoges where the minimal threshold was substantially raised, and in Toulouse where the maximal threshold was lowered.

The system is still imperfect, as the temperatures are not the only factors to consider regarding heat load. The humidity may also be interesting, but cannot be used in a predictive system due to the difficulties of forecasting. The characteristic of the summer before the heat wave may also be of importance. Indeed, the dramatic impact of the 2003 heat wave may partly be explained by a very warm summer, with elevated temperatures in June and July, which created a state of exhaustion in the most vulnerable groups of population. In addition, the forecasting of meteorological parameters is always associated with an uncertainty that has to be dealt with. For instance, it was observed in 2004 that the maximal temperatures were slightly underestimated, while the minimal temperatures were overestimated. These errors were small and infrequent (<1°C for 76% of the days) but still interfered with the specificity of the system. Indeed, situations when the indicators are close to the thresholds are usual and highly sensitive to even minor uncertainties in the forecasting. This led to the definition of additional qualitative criteria to consider: humidity, wind, air pollution, intensity and duration of the heat wave, sanitary signals. For borderline situations, the additional information is discussed with the health scientists and with the meteorologists. It is believed that this will help in improving the communicability and the efficiency of the system, which were the main concerns for the users of this system.

Cities	2004		2005	
	Minimal threshold	Maximal threshold	Minimal threshold	Maximal threshold
Bordeaux	22	36	21	35
Dijon	19	34	19	34
Grenoble	15	35	19	34
Lille	15	32	18	31
Limoges	16	36	20	33
Lyon	20	34	20	34
Marseille	22	34	22	34
Nantes	20	33	20	34
Nice	24	30	24	31
Paris	21	31	21	31
Strasbourg	17	35	19	34
Toulouse	21	38	21	36
Tours	17	34	19	35

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