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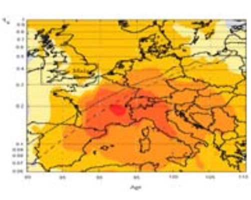
Report on excess mortality in Europe during summer 2003

(EU Community Action Programme for Public Health, Grant Agreement 2005114)

by JM Robine, SL Cheung, S Le Roy, H Van Oyen et F R Herrmann



2003 Heat Wave Project

La Canicule de 2003 en Europe

(In English)

Report on excess mortality in Europe during summer 2003

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Abstract

Everyone undoubtedly remembers the 15,000 additional deaths in France caused by the heat wave in August 2003, yet no-one knows the total number of victims at European scale. For this reason, the excess mortality cumulated during summer 2003 has recently been assessed at the request of the European Union. The study covers sixteen countries.

*The numbers of deaths are available for each day by gender, age and region (NUTS 2), since January 1st 1998, i.e. 19,098,574 non-empty cells for the daily number of deaths. To be able to compare the years and European countries with very different population sizes, we have calculated the daily death frequency in relation to the yearly total number of deaths. We have defined standard boundaries, first and third quartile more or less 1.5*IQR (inter-quartile range), to identify the extreme values and more or less 3*IQR to identify the exceptional extreme values.*

An analysis of the reference period - 1998-2002 - shows that the day only explains between 2 and 3% of the variance in deaths observed during the summer period, whereas the year of observation and the country each explain between 5% and 6%. This is negligible and we can thus analyse the summer mortality in a single block. Three main mortality peaks are apparent during summer 2003: the peak on June 13th, the double peak on July 16th-21th and lastly the peak on August 12th-13th which seems exceptionally pronounced. We also observe a persistent excess mortality at the end of June and during September. Out of a total of 1,952 summer days corresponding to the sixteen countries studied, 147 exceed the boundaries marking the high extreme values, i.e. .7.5% of the total. Fifty days exceed the boundaries marking the exceptional values.

In total, more than 80,000 additional deaths were recorded in 2003 in the twelve countries concerned by excess mortality compared to the 1998-2002 period. Whereas 70,000 of these additional deaths occurred during the summer, still over 7,000 occurred afterwards. Nearly 45,000 additional deaths were recorded in August alone, as well as more than 11,000 in June, more than 10,000 in July and nearly 5,000 in September. The mortality crisis of early August extended over the two weeks between August 3rd and 16th. 15,000 additional deaths were recorded in the first week and nearly 24,000 in the second. The excess mortality in this second week reached the exceptional value of 96.5% in France and over 40% in Portugal, Italy, Spain and Luxembourg. Excess mortality exceeded 20% in Germany, Switzerland and Belgium and 10% in all the other countries.

European regional maps (NUTS 2) outline the early August mortality crisis breaking national frontiers. The crisis caused major distortions in the gender and age structure of death. On August 12th in France the proportion of deaths of the over-95s reached

8.9% of the total, an increase of 46% compared with the expected figure. The female death share increased by 21% on the same day. Beyond a return to normal, no overall harvesting effect was observed in the weeks and months following the mortality crisis.

Our observations suggest that next to the exceptional mortality crisis, which occurred at the beginning of August and which was so large that none could ignore it, there may be a sequence of minor crises, which pass almost unnoticed. Yet, the cumulative result over the whole summer period can globally be just as significant. In France and Italy the cumulated excess mortality from June 1st to September 30th 2003 - +19,490 and +20,089 deaths respectively -, have different accumulating profiles. These results suggest that centralising daily deaths at sufficiently large scale, including grouping regions or countries with small populations, should improve the monitoring of summer excess mortality potentially due to global warming.

The excess mortality cumulated during summer 2003 has recently been assessed at the request of the European Union. Everyone remembers the 15,000 additional deaths in France caused by the heat wave in August 2003, but no-one knows the total number of victims at European scale although more than 70 scientific papers and reports related to this event have been already published (Cheung et al, 2007). Press releases issued by statistics institutes in 2004 and 2005 referred to major excess mortality throughout summer 2003, potentially reaching 20,000 deaths in both Spain and Italy. Other countries like Germany have yet to publish figures on the excess mortality in summer 2003 at the national level. Because of the variation in data availability and the current concerns relating to global warming, the European Union launched a call for tenders for a global study on the excess mortality in Europe during summer 2003 (EU Community Action Programme for Public Health, Grant Agreement 2005114).[1]

Material and method

To carry out this study, we collected daily numbers of deaths by gender and age at regional level (NUTS 2)[2], in all countries concerned by the summer 2003 heat-wave: twelve countries where there is a report indicating a possible excess mortality[3] and all their surrounding countries (4 countries) serving as controls[4]. To obtain the daily number of deaths from January 1st 1998 to December 31st 2004[5], we had one contact per country, usually within the Central Statistical Office. However, in Germany, our correspondent had to compile the data from sixteen Landers.

To make the years, countries and regions (NUTS 2) comparable, we calculated the death frequency by dividing for each year the daily death number by the annual total. Assuming no seasonal variations or daily fluctuations, it was reasonable to expect to observe 0.27% (100/365) of all annual deaths on any given day. The numbers and daily frequencies were available for each day by gender, age and region

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[1] Moreover differences in periods of time studied, methods used, age selection and various thresholds prevent comparison or meta-analysis of existing studies.

[2] The Nomenclature of Territorial Units for Statistics (NUTS) http://en.wikipedia.org/wiki/Category:NUTS_2_Statistical_Regions_of_Europe

[3] Germany, England, Belgium, Croatia, Spain, France, Italy, Luxembourg, Netherlands, Portugal, Slovenia and Switzerland.

[4] Austria, Denmark, Poland and Czech Republic.

[5] With the exception of Italy which provided us with data up to December 31st 2003 only.Some countries have provided data up to 2005.

(NUTS 2) since January 1st 1998, i.e. 19,098,574 non-empty cells for the daily death numbers.

The analysis covered firstly (1) the seasonality of deaths in Europe during the 1998- 2002 period to define a reference framework and a common summer period. Next, the analysis concentrated on (2) the characteristics of summer daily mortality in Europe during the same period, to set thresholds for identifying exceptional days of deficit or excess mortality. We have adopted standard boundaries, first and third quartile (Q_1 and Q_3) more or less 1.5*IQR (inter-quartile range), to identify the extreme values (mild outliers: Q_1-1.5*IQR; Q_3+1.5*IQR) and more or less 3*IQR to identify the exceptional extreme values (Q_1-3*IQR; Q_3+3*IQR) (Tukey, 1977). This analysis included 9,760 summer days (122 days from June 1st to September 30th * 5 years * 16 countries). The analysis then moved on to summer 2003 itself. We firstly examined (3) the variations in daily mortality in all sixteen European countries, by calculating the delta between the number of daily deaths observed during summer 2003 and the average number of deaths on the same day during the five years of 1998-2002 reference period. A positive delta means a number of deaths higher than the last five-year average and a negative delta a lower number. To overcome population sizes in the countries, we used the daily death frequency and the frequencies cumulated between June 1st and September 30th to describe their profile. To make it easier to understand the magnitude of the decreased or excess mortality, we divided all the daily frequencies by the value of the median of the daily frequency experienced during the summers between 1998 and 2002. This conversion, covering all the key parameters (25th percentile, 75th percentile, threshold values marking the extreme values), rescales all the values observed around the unit. It is therefore immediately possible to interpret the daily mortality on a given day as a multiple of the median value; a value of 1.6, for example, signifies an increase by 1.6 and a value of 0.5 a decrease of a factor two of the daily deaths compared with the median value of the 1998-2002 summers. Adding the deviations over the 122 summer days, the deviation from 122 (122 * the transformed median value), provides us with an instant information on the relative significance of the cumulated decreased or excess mortality throughout summer 2003. We then calculated (4) the daily excess mortality in 2003 for each country compared with the average deaths noted on the same day from 1998 to 2002. The results presented are grouped per month and mortality condition (summer or non-summer). Lastly, we focused specifically (5) on the excess mortality peak at the beginning of the month of August 2003. We produced maps at NUTS 2 level to specify more accurately the geographical boundaries of different levels of excess mortality within each country. A first map illustrates the importance of excess mortality cumulated over the two weeks of August 3rd-16th (i.e. from Day 215 to Day 228 of the year, DOY). A second map represents the excess mortality on the most lethal day of the summer, August 12th 2003 (i.e. DOY 224). Lastly (6), a series of ratios shows the distortions in the proportion of deaths of older people (65+, 75+, 85+ and 95+) and in the share of female deaths within the summer daily deaths that occurred at the same time as the 2003 August death peak. Every ratio, for example for the proportion of deaths of the over-65s (ratio 65+) or for the proportion of women (ratio female), was calculated by dividing the share of deaths corresponding to a given day by the average share noted over the whole of summer 2003. The analysis initially performed for both genders together will be repeated for each gender.

Results

1. Seasonality of deaths in Europe

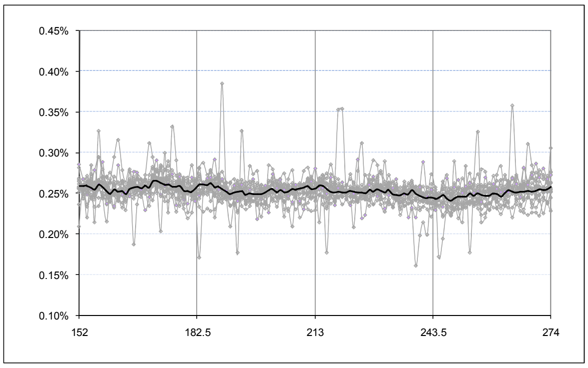
The distribution of daily deaths occurring between 1998 and 2002 reveals identical seasonality in the sixteen European countries studied, with (i) low mortality summer conditions from June to September, where the daily mortality appears to be constant and (ii) non-summer conditions from October to May, with a rise in mortality from October to December, a winter peak in January and February followed by a drop in mortality from March to May. Various parametric and non-parametric models were used to explore these data. In particular polynomial regression models, weighted, and robust, single and multiple and from 1 to 4 degrees, were applied to each set of mortality conditions to determine the proportion of variance in the daily death frequency explained by the days of the year. The multiple models were adjusted for year and country by introducing dummy variables.

Table 1: R squared (expressed as a percentage) of weighted, robust polynomial regressions, used to determine the proportion of variance of the daily death frequency explained by day of the year for each set of mortality conditions (summer and non-summer), sixteen European countries from 1998 to 2002

		June to September		October to May	
		Crude	Adjusted	Crude	Adjusted
	Year	5.8	--	0.5	--
	Country	4.8	--	0.4	--
$y = a_0 + a_1x$	Day	2.4	13.0	0.1	1.0
$y = a_0 + a_1x + a_2x^2$	Day	2.5	13.1	37.3	38.2
$y = a_0 + a_1x + a_2x^2 + a_3x^3$	Day	3.1	13.7	37.4	38.3
$y = a_0 + a_1x + a_2x^2 + a_3x^3 + a_4x^4$	Day	3.4	14.0	42.7	43.6

Table 1 shows that the models with a degree higher than 1 do not improve the prediction quality for the summer period. Similarly, the models with a degree higher than 2 do not improve the prediction quality for the non-summer period. In all models, during the summer period, the summer day only explains between 2% and 3% of the variance, whereas the year of observation and the country each explain between 5% and 6%. This is negligible and the summer mortality was analysed as a single block (see Figure 1).

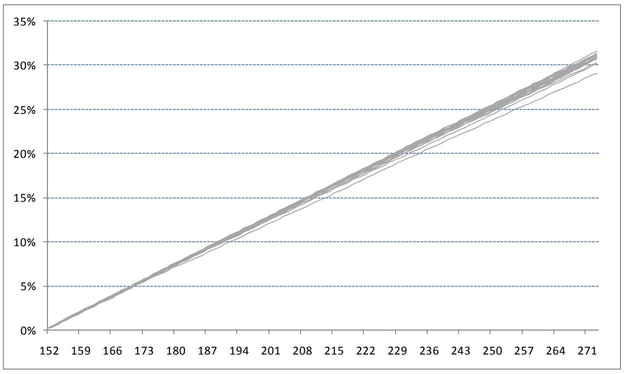
Figure 1: Distribution of the daily death frequency during summer, from June 1st to September 30th*, for each of the sixteen European countries and for them all together averaged over five years, 1998 to 2002



*DOY 152, the 152nd Day Of the Year corresponds to June 1st and DOY 273 to September 30th on a regular year. On a leap year, DOYS are shifted by one after February 29th

Out of the summer period, the day explains around 40% of the variance in the daily death frequency in all models with a degree higher than 1. Figure 2 summarises the slight differences in summer mortality observed in the various countries, by cumulating the daily death frequency from June 1st to September 30th. The two extremes are the Czech Republic, where 31.6% of annual mortality is cumulated during the summer, and Portugal, with only 29.1% cumulated during the same period, i.e. a discrepancy of only 2.5%.

Figure 2: Summer mortality accumulation, from June 1st to September 30th*, for the sixteen European countries as a percentage of annual mortality averaged over five years, 1998 to 2002

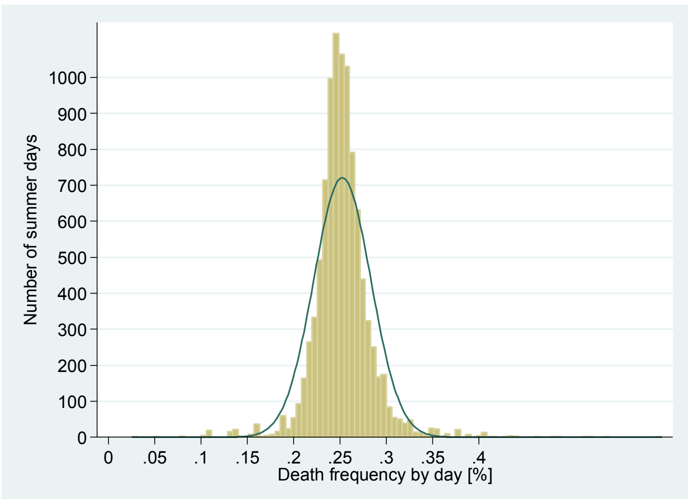


*DOY 152, the 152nd Day Of the Year corresponds to June 1st and DOY 273 to September 30th on a regular year. On a leap year, DOYS are shifted by one after February 29th

2. Summer mortality characteristics in Europe

The 9,760 daily summer death frequencies experienced in the sixteen European countries between 1998 and 2002 are distributed symmetrically around a median frequency of 0.2506 (average 0.2525). The distribution seems very concentrated compared to a normal distribution (see Figure 3); 50% of observations are between 0.2377 (25th percentile) and 0.2655 (75th percentile). The boundaries defining the extreme values are 0.1961 and 0.3072 for the minor outliers and 0.1544 and 0.3489 for the exceptional values. 5.68% of observations (n=554) are outliers, beyond the boundaries defining the minor extreme values and 1.78% (n=174) are extreme outliers, i.e. beyond the boundaries defining the exceptional extreme values.

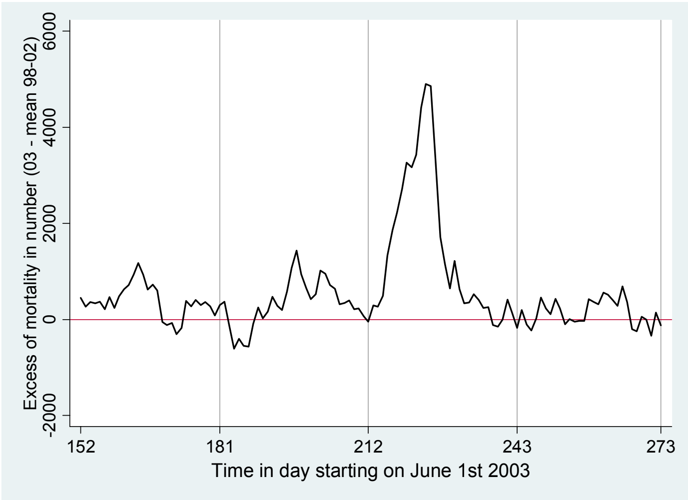
Figure 3: Distribution of the summer daily mortality for sixteen European countries, 1998 to 2002



3. Variations in daily mortality during summer 2003

Figure 4 represents the variations in daily mortality during summer 2003 for all the sixteen European countries, using the delta between the number of daily deaths observed during the summer and the average number of deaths, noted on the same day, during the five years in the 1998-2002 reference period. A delta higher than zero therefore indicates a number of daily deaths higher than the average of the last five years and a delta lower than zero the reverse.

Figure 4: Delta between the number of daily deaths noted during summer 2003* and the average number of deaths noted on the same day during the five years of the 1998-2002 reference period for the sixteen European countries studied



*DOY 152, the 152nd Day Of the Year corresponds to June 1st, DOY 181 to June 30th, DOY 212 to July 31st, DOY 243 to August 31st and DOY 273 to September 30th

Within the sixteen European countries studied, out of the 122 days of summer 2003, 27 days presented a delta lower than zero inducing a total deficit of 5,045 deaths compared to 95 days with a delta higher than zero creating a total excess mortality of 74,483 deaths. It is clear that both gaps do not balance each other. Excess mortality was a characteristic phenomenon throughout summer 2003 and affected a major part of Europe. In particular three main peaks exceeding the threshold of 1,000 daily additional deaths are striking (Figure 4); June 13th peak at the end of the second week of summer, July 16th and 21st double peaks during the seventh and eighth weeks and lastly August 12th-13th peak during the eleventh week of summer, which seems exceptional given its size. Note also excess mortality persisting at the end of June during the fourth week of summer; in early September during the fourteenth and fifteenth weeks and during the sixteenth and seventeenth weeks, with a slight peak on 22 September.

Profiles of the different countries

Out of a total of 1,952 summer days corresponding to the sixteen countries studied (122 days * 16 countries), 145 are outliers and go beyond the boundaries marking the high extreme values, i.e. 7.5% of the total, including three days (0.6%) in the four control countries and 144 days (9.8%) in the twelve countries concerned by the excess mortality of summer 2003. Fifty days are extreme outliers and exceed the boundaries marking the exceptional high extreme values. They only involve countries in the group of twelve, i.e. 3.4% of the total observations. This is more than three times the figures observed during the 1998-2002 reference period. The countries most affected by these exceptionally high daily death frequencies are Luxembourg (twenty days), Portugal (eleven days), France (nine days) and Italy (four days). The other countries experienced a maximum of one or two days with a death frequency exceeding the exceptional high values. None of these days were recorded in England and Wales, Spain or the Netherlands. Figure 1A annexed details the situation in each country. Remember that the countries can be compared as the figures are based on the comparison of the daily death frequencies, thus overcoming the differences in the size of their populations. The daily frequencies were divided by the value of the median frequency estimated during the summers of 1998 to 2002. As explained in the methods section, this conversion rescales all the observed frequencies around the unit and provides an interpretation of the the daily mortality on a given day as a multiple of the median value.

The first peak in mid-June is found mainly in Italy and Croatia and, to a lesser degree, Spain. The peak seems to be offset by a few days in Portugal where it occurred on June 20th. All this created a considerable excess mortality period at the start of the summer, specific to southern countries. This period of excess mortality remained almost unnoticed. The second and double peak centred on July 16th-21st involves the Netherlands, England and Wales, Belgium, Luxembourg, France, Germany, Switzerland and, to a lesser degree, Spain. The excess mortality occurs simultaneous and is prominent in all Western European countries. Again, the event remained unnoticed with the exception of a reporting on the excess in mortality in July 2003 in the Netherlands (De Beer and Harmsen, 2003). The third peak centring on August 12th and 13th involves firstly France, Italy, Portugal and Luxembourg. It is also clearly visible in Germany, England and Wales, Belgium and Switzerland. Lastly, although less sharp, it also appears in the Dutch and Spanish daily death series.

The accumulation of transformated daily death frequencies over the 122 days of summer 2003 (see Figure 2A) shows a contrast between (i) countries such as France and Germany, which deviate abruptly from the anticipated trend during the first two weeks of August, by cumulating excess mortality which will not be offset later on, (ii) countries like Spain and Italy which move far more gradually away from the trend in several waves covering the beginning of the summer until the end of August, (iii) countries like Portugal which tend towards sub-mortality prior to the early August peak and which recover excess mortality before the end of the summer and lastly (iv) countries like England and Wales which ultimately drift only slightly away from the anticipated trend, just like the control countries not concerned by the heat wave.

4. Excess mortality in 2003 compared with the 1998-2002 average

Table 2 presents the total numbers of surplus or deficit deaths before, during and after summer 2003 for each country, detailing the summer months. It also expresses the corresponding excess mortality ratios as a percentage. In all, more than 80,000 additional deaths were recorded in 2003 in the twelve countries concerned by excess mortality, i.e. an excess of 2.5% compared to 1998-2002. In the same year 2003, the four control countries recorded 1,400 fewer deaths, i.e. a drop of 0.2% compared with 1998-2002. Although 70,000 of these additional deaths occurred during the summer, over 3,000 occurred before the summer and 7,000 afterwards. The countries most affected by this excess summer mortality were Luxembourg, Spain, France and Italy, where mortality increased by 14.3%, 13.7%, 11.8% and 11.6% respectively. Then we observe an 8.7% increase in mortality in Portugal, a mortality increase by about 5% in Croatia, Slovenia and Switzerland. An increase in mortality around 3.5% and lower was recorded in Germany, Belgium and the Netherlands, whereas no increase was observed in England and Wales and the overall mortality dropped by 1% during summer 2003 in the control countries.
In August 2003 alone, nearly 45,000 additional deaths were recorded in the twelve countries concerned, including 15,251 in France (+37%), 9,713 in Italy (+21.8%), 7,295 in Germany (+11%), 6,461 in Spain (+22.9%) and 1,987 in England and Wales (+4.9%). In less-populated countries the numbers are lower,

but excess mortality can be relatively very significant as in Luxembourg where 73 additional deaths increased mortality by 25%. Belgium, Netherlands and Switzerland each accounted for about five hundred additional deaths, respectively +5.3%, +5.2% and +9.8%. Excess mortality reached 9.9% in Slovenia with 144 additional deaths and 6.8% in Croatia with 269 additional deaths. The mortality dropped by more than 1% during August 2003 in the control countries.

Independently of the month of August, 11,000 additional deaths were recorded in June (including 5,274 in Italy and 4,268 in Spain), over 10,000 in July (again including 4,318 in Italy and 2,751 in Spain) and nearly 5,000 in September (including 1,611 in Spain, 1,051 in France and 783 in Italy). These results suggest that a succession of minor crises can co-exist, mainly unnoticed, together with an exceptional mortality crisis like the one observed at the beginning of August 2003, which was so large that it cannot be ignored. However the cumulated results of these lesser crises over the summer are globally just as significant. France and Italy thus cumulated the same excess mortality from June 1st to September 30th 2003 - +19,490 and +20,089 deaths respectively -, with very different cumulating profiles during the summer.

Table 2: Delta between the number of deaths observed during 2003 and the average number of deaths noted during the five years of the reference period and the excess mortality ratio compared with the same 1998-2002 reference period (expressed as a percentage) for various periods in 2003 (before the summer, during the summer and after the summer) and for various countries.

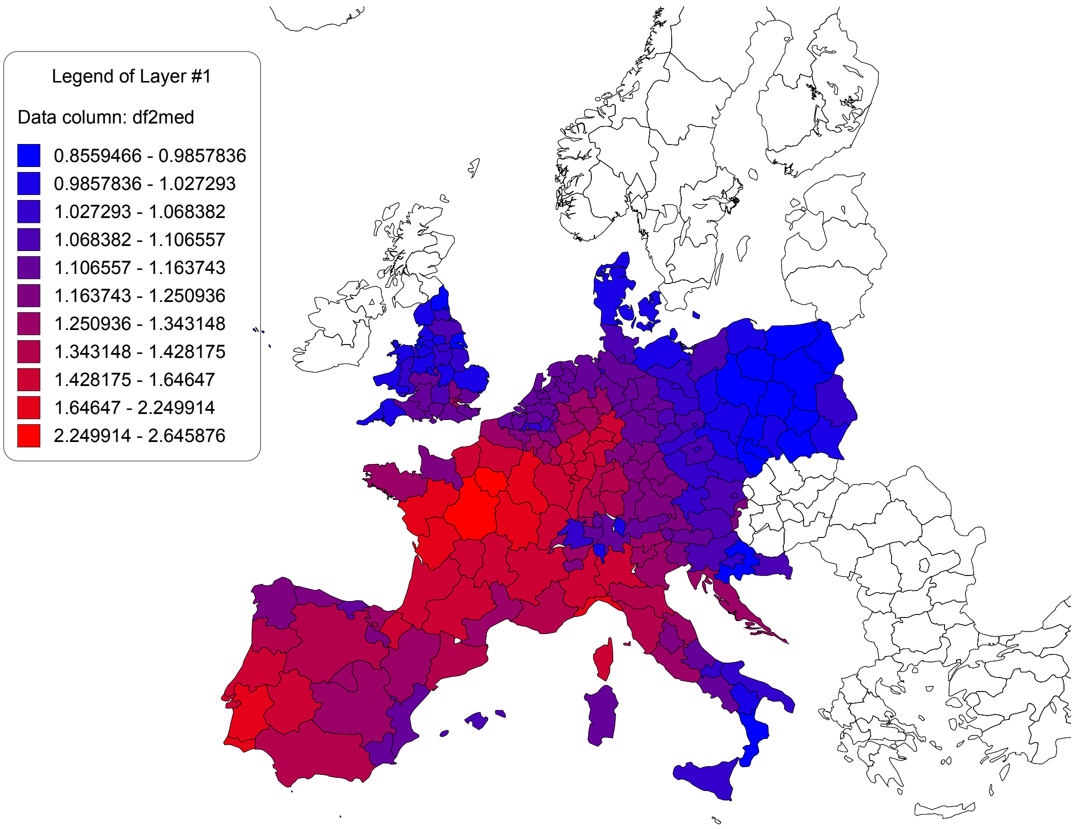
	Before summer		Summer										After summer		Total of the year	
			June		July		August		September		Total					
	Nb	Ratio	Nb	Ratio	Nb	Ratio	Nb	Ratio	Nb	Ratio	Nb	Ratio	NB	Ratio	Nb	Ratio
Countries involved in the August 2003 excess of mortality																
Belgium	-4	-0.01	139	1.72	162	1.97	438	5.31	436	5.57	1175	3.62	1356	5.11	2528	2.41
Switzerland	92	0.34	253	5.30	187	3.89	469	9.81	130	2.75	1039	5.45	-148	-0.93	984	1.58
Germany	9290	2.55	642	0.98	1159	1.73	7295	10.97	259	0.40	9355	3.56	-5760	-2.69	12885	1.53
Spain	-1464	-0.90	4268	15.49	2751	9.64	6461	22.86	1611	6.21	15090	13.68	7249	7.95	20875	5.74
France	-3977	-1.70	1482	3.60	1706	4.06	15251	36.93	1051	2.62	19490	11.84	3415	2.53	18928	3.55
Croatia	882	3.95	193	4.85	157	3.98	269	6.83	169	4.49	788	5.04	5	0.04	1675	3.29
Italy	5575	2.24	5274	12.12	4318	9.72	9713	21.81	783	1.94	20089	11.63	-2487	-1.76	23177	4.12
Luxemburg	57	3.47	32	10.81	27	9.29	73	25.00	34	12.22	166	14.34	74	7.85	297	7.95
Netherlands	304	0.50	78	0.71	11	0.10	578	5.24	297	2.79	965	2.20	503	1.42	1771	1.26
Portugal	-2068	-4.26	220	2.83	100	1.28	2196	27.75	179	2.44	2696	8.73	2072	7.76	2699	2.54
Slovenia	351	4.30	13	0.87	62	4.21	144	9.93	70	4.86	289	4.96	74	1.55	714	3.81
England & Wales	-5695	-2.41	-1080	-2.64	-504	-1.21	1987	4.90	-103	-0.26	301	0.18	2025	1.44	-3369	-0.62
Total	3342	0.23	11515	4.50	10137	3.88	44876	17.34	4917	1.99	71445	6.99	8377	0.99	83164	2.50
Countries used as controls																
Austria	708	2.12	-42	-0.71	172	2.86	159	2.63	57	0.99	345	1.45	-645	-3.30	408	0.53
Czech Republic	2408	5.17	207	2.43	190	2.18	58	0.67	-37	-0.43	418	1.22	-335	-1.20	2491	2.29
Poland	1916	7.42	-487	-10.71	-543	-11.55	-918	-19.59	-652	-14.35	-2600	-14.07	-3436	-22.94	-4119	-6.95
Denmark	-113	-0.07	-43	-0.15	-92	-0.31	-49	-0.17	14	0.05	-170	-0.15	92	0.10	-191	-0.05
Total	4920	1.86	-365	-0.77	-273	-0.56	-750	-1.56	-618	-1.31	-2006	-1.05	-4325	-2.74	-1411	-0.23

5. Excess mortality peak of early August 2003

The mortality crisis of early August extended over the two weeks between August 3rd and 16th - the tenth and eleventh weeks of summer. 15,000 additional deaths were recorded in the countries studied during the tenth week and nearly 24,000 during the eleventh week. The excess mortality ratio in this second week reached the exceptional value of 96.5% in France and very high values in Portugal (+48.9%), Italy (+45.4%), Spain (+41.2%) and Luxembourg (+40.8%). Excess mortality reached 28.9%, 26.7% and 21.6% respectively in Germany, Switzerland and Belgium. It exceeded 10% in all countries except Denmark, Poland and Czech Republic. Even in Austria mortality increased by 12.6% in the week of August 10th-16th. It is important to notice that beyond a return to normal, no overall harvesting effect was observed in the weeks and months following the mortality crisis in early August 2003. Mortality remained high just about everywhere until the end of the summer. Only Germany, Italy and Switzerland recorded slight drops in deaths after the summer (see Table 2), with 5,760 fewer deaths recorded for Germany from October to December 2003 (- 2.7%), 2,487 fewer deaths for Italy (-1.8%) and 148 fewer deaths for Switzerland (-0.9%).

We analysed the daily death frequencies at NUTS 2 level to determine the geographical limits of the mortality peak of early August 2003. Map 1 represents the cumulative excess mortality from August 3rd to 16th, the period encompassing the peak represented in Figure 4, and Map 2 represents the excess mortality recorded on August 12th, the most lethal day of summer 2003.

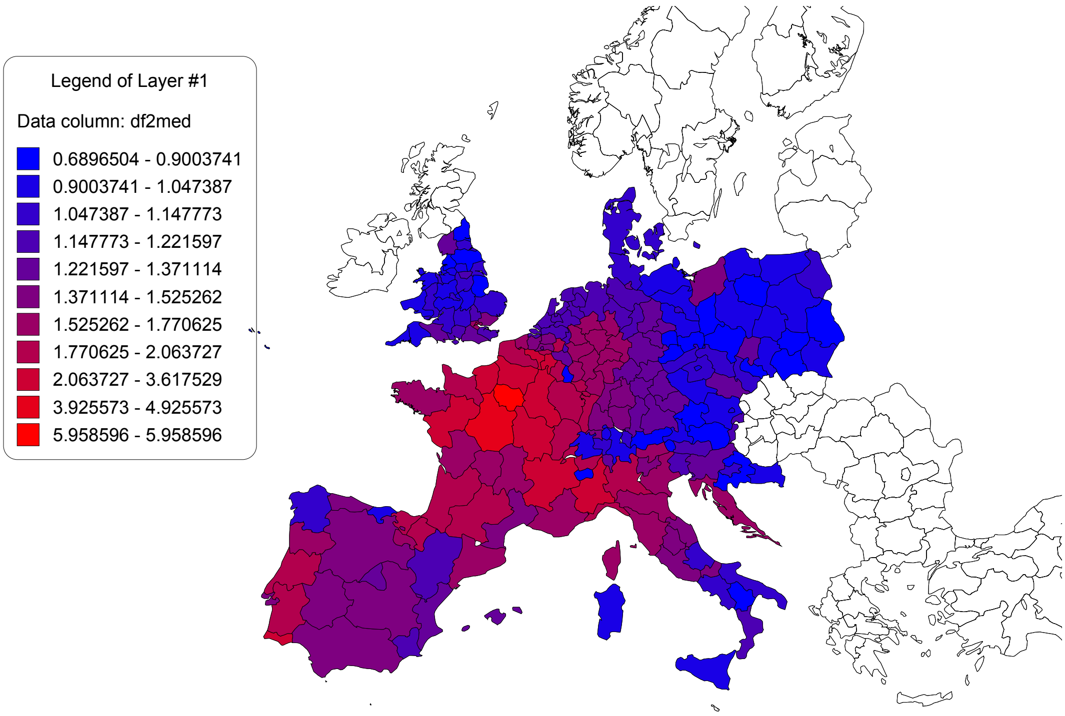
Map 1: Daily death frequencies cumulated from August 3rd to 16th 2003, divided by fourteen times the daily reference median frequency for 1998-2002 summer period, sixteen European countries, NUTS 2.



The regions most affected lie in a south-west north-east axis, from the Algarve in Southern Portugal to

Westphalia in Germany. A secondary axis starts in Southern England and continues towards Latium in Central Italy and towards Croatia. The most significant mortality focal spots are in France (Ile-de-France and the neighbouring region of Centre), where mortality recorded between August 3rd and 16th is double that expected. Six regions - two in Southern Portugal (Algarve and Alentejo) and four in France to the west and east of the Ile-de-France and Centre (Pays-de-la-Loire, Poitou-Charentes, Burgundy and Franche-Comté) recorded a very high excess mortality during these two weeks (between 65% and 125%). Switzerland as some coastal regions (a.o. Brittany in France and Galicia, Murcia and Valencia in Spain) seem to have been relatively spared. The south-eastern boundaries of the mortality crisis are poorly defined as it was not possible to obtain the necessary data in Bosnia-Herzegovina or Yugoslavia.

Map 2: Daily death frequency noted on August 12th 2003, divided by the daily reference median frequency for the 1998-2002 summer period, sixteen European countries, NUTS 2.

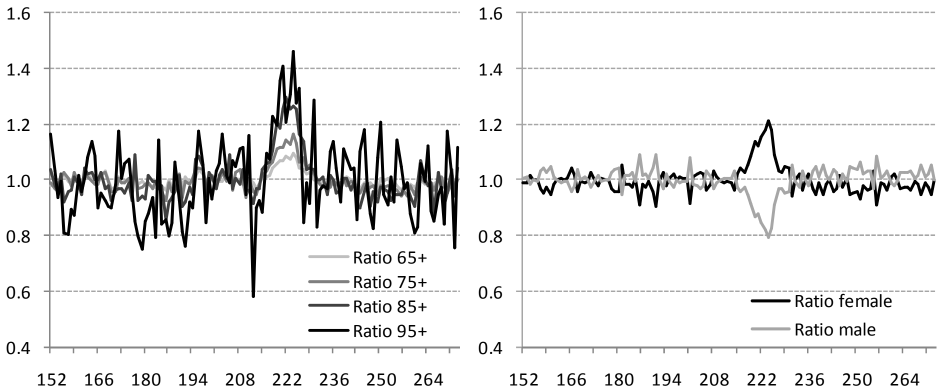


On the most lethal day of summer 2003 - August 12th - mortality recorded in Ile-de- France was over five times that expected. It was over four times the expected mortality in the Centre region (France) and twice the expected mortality in Algarve in Portugal, in six French regions (Pays-de-Loire, Haute-Normandie, Picardy, Champagne-Ardenne, Burgundy and Rhône-Alpes), in three Belgian regions (Namur, Hainaut and Comines-Warneton), in Piedmont in Italy and in the Greater London Area in England.

6. Distortion of death structure by age and gender

The August 2003 mortality crisis caused major distortions in the death structure by age and gender which are illustrated in Figure 5 using France as the example. Whereas on average during the summer 2003 the share of over-65s deaths represents 79% of the total deaths in France, it reached 86.5% on August 12th, i.e. an increase of 9.5%. The share of over-75s deaths reached 73.1% on the same day, an increase of 16.5%, and the share of the over-85s deaths 41.2%, i.e. an increase of 26.8%. Lastly, the share of over-95s deaths reached 8.9% on August 12th, an increase of 46%. These distortions in the age distribution of deaths become greater at older ages. This implies that the excess mortality varied considerably with age and that it rose as the age increased. To estimate the age specific mortality rates, population data defining the population at risk at each age are necessary. However, at population level, it is extremely difficult to acquire exact knowledge of population size by gender and age which are alive on a given day. Daily distortions in the relative distribution of deaths by age should, nevertheless, help us estimating the excess mortality linked to age.

Figure 5: Distortion of the death structure by age and gender in France during summer 2003*



*DOY 152, the 152nd Day Of the Year corresponds to June 1st, DOY 181 to June 30th, DOY 212 to July 31st, DOY 243 to August 31st and DOY 273 to September 30th

The structure of deaths by gender also varied considerably during the mortality crisis. Whereas on average during the summer 2003 more men died than women, 50.6% against 49.4%, the share of female deaths reached 59.9% on August 12th whereas the share of male deaths fell to 40.1%, i.e. an increase of 21% in the share of female deaths and an equivalent drop in the share of male deaths.

Discussion

In comparison with the 1998-2002 period, more than 80,000 additional deaths were recorded in 2003 in the twelve countries concerned by excess mortality. Whereas 70,000 of these additional deaths occurred during the summer, over 7,000 took place afterwards. Nearly 45,000 additional deaths were recorded in August alone, as well as more than 11,000 in June, more than 10,000 in July and nearly 5,000 in September. The mortality crisis of early August extended over the two weeks between August 3rd and 16th. 15,000 additional deaths were recorded in the first week and nearly 24,000 in the second. The excess mortality in this second week reached the exceptional increase of 96.5% in France and over 40% in Portugal, Italy, Spain and Luxembourg. Excess mortality exceeded 20% in Germany, Switzerland and Belgium and 10% in all the other countries.

European regional maps (NUTS 2) show the geographical distribution of the early August mortality crisis indicating the cross-border expansion. The crisis caused major distortions in the structure of deaths by age and by gender. On August 12th, in France, the share of deaths of the over-95s reached 8.9% of the total, an increase of 46% compared with the expected figure. The female death share increased by 21% on the same day. Beyond a return to normal, no overall harvesting effect was observed in the weeks and months following the mortality crisis.

Our observations suggest that a succession of minor crises can co-exist with an exceptional mortality crisis like the one at the beginning of August that none can ignore. These smaller crises pass almost unnoticed and yet the cumulative results over the summer can globally be just as significant. France and Italy thus cumulated the same excess mortality in summer 2003 - +19,490 and +20,089 deaths respectively - , with very different accumulating profiles. These results suggest that centralising daily deaths at sufficiently large scale, like grouping regions or countries with small populations, should improve monitoring of summer excess mortality potentially due to global warming.

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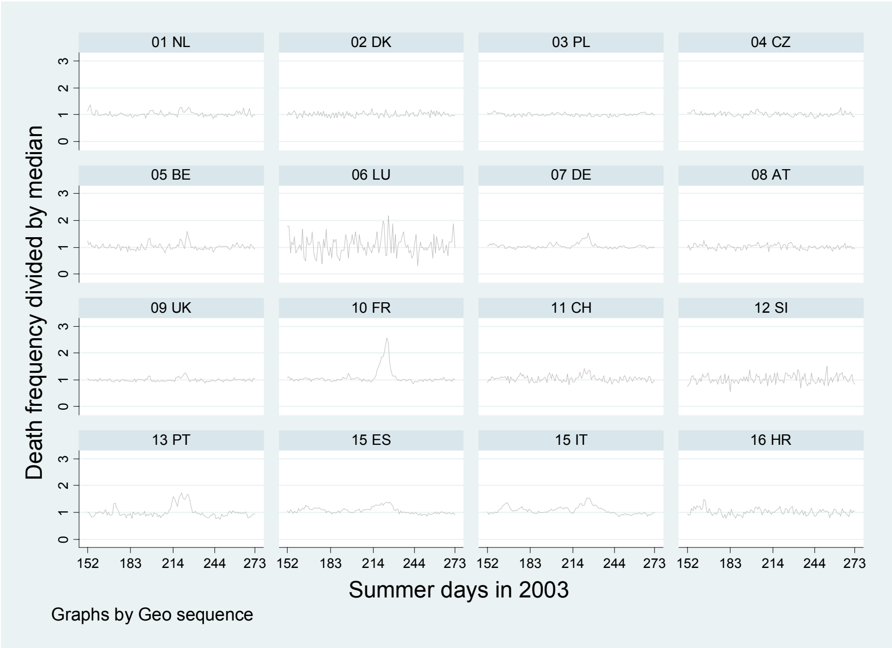
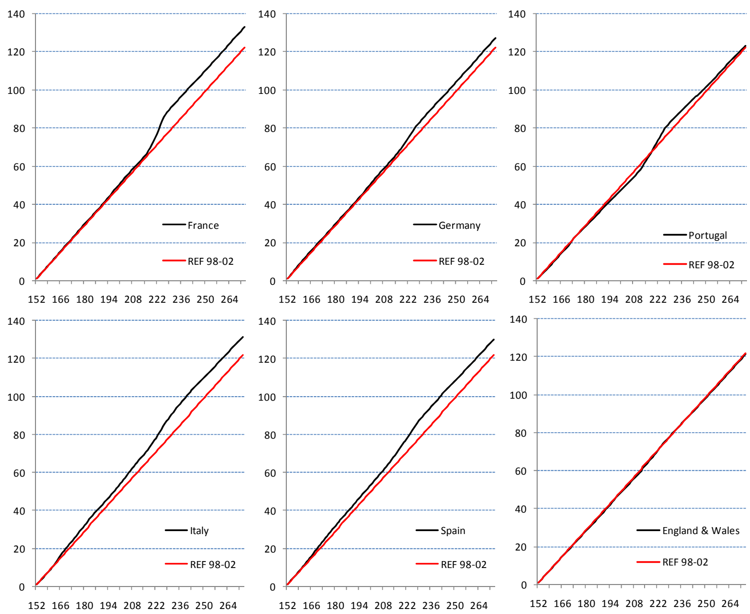
Cheung SLK, Robine JM, van Oyen H, Griffiths C and Herrmann F (2007) *The 2003 Heat wave in Europe, a review of the literature*. Montpellier, The 2003 Heat Wave Project (EU Community Action Programme for Public Health, Grant Agreement 2005114).

Figure 1A: Excess mortality country profiles during the summer 2003, from June 1st to September 30th*, for sixteen European countries



*DOY 152, the 152nd Day Of the Year corresponds to June 1st, DOY 181 to June 30th, DOY 212 to July 31st, DOY 243 to August 31st and DOY 273 to September 30th

Figure 2A: Mortality accumulation from June 1st to September 30th for six European countries concerned by the excess mortality of the summer 2003



*DOY 152, the 152nd Day Of the Year corresponds to June 1st, DOY 181 to June 30th, DOY 212 to July 31st, DOY 243 to August 31st and DOY 273 to September 30th