Chapter 6
Surface Plots of Rates of Mortality Improvement

6.1 From Smoothed Death Rates to Rates of Mortality Improvement

The colors and contour lines in Fig. 5.3 suggest also a change in pace over time: Each level of mortality seems to change its slope in the early 1990s. We argue that those trend changes are better illustrated with "rates of mortality improvement", which we labeled "ROMIS", than with (smoothed) surface maps of mortality. Given death rates at age x in year t, $m(x, t)$, we defined the rates of mortality improvement, ρ, by assuming a constant rate of change within the period of comparison. In this monograph, we only used annual changes. Hence:

$$\rho(x, t) = -\log_e \left(\frac{m\,(x, t + 1)}{m\,(x, t)} \right)$$

It is simply a reformulation of the standard equation for growth with a constant rate r: $P(t) = P(0)e^{rt}$ (e.g., Keyfitz 1977). The minus sign ensures to have positive numbers for survival improvements. We expressed the respective values for ρ in percent. It is comparable to Kannisto et al. (1994) who used a discrete version of the growth equation and aggregated several ages and years.

Figure 6.1 illustrates those ROMIS again with data for Estonian women. To provide a more comprehensive overview, we expanded the age range as well as calendar time. No change or negligible changes ($-0.5\% \leq \rho \leq 0.5\%$) are depicted in white. Slight improvements ($0.5\% < \rho \leq 2.0\%$) are shown in three shades of blue, larger improvements in green colors ($2.0\% < \rho \leq 4.0\%$) and very strong improvements ($\rho > 4.0\%$) in red colors and yellow. If mortality increased, i.e., the survival conditions worsened, we used darker shades of gray for larger mortality increases. Please note that an annual change of $\rho = 0.035 = 3.5\%$ cuts mortality

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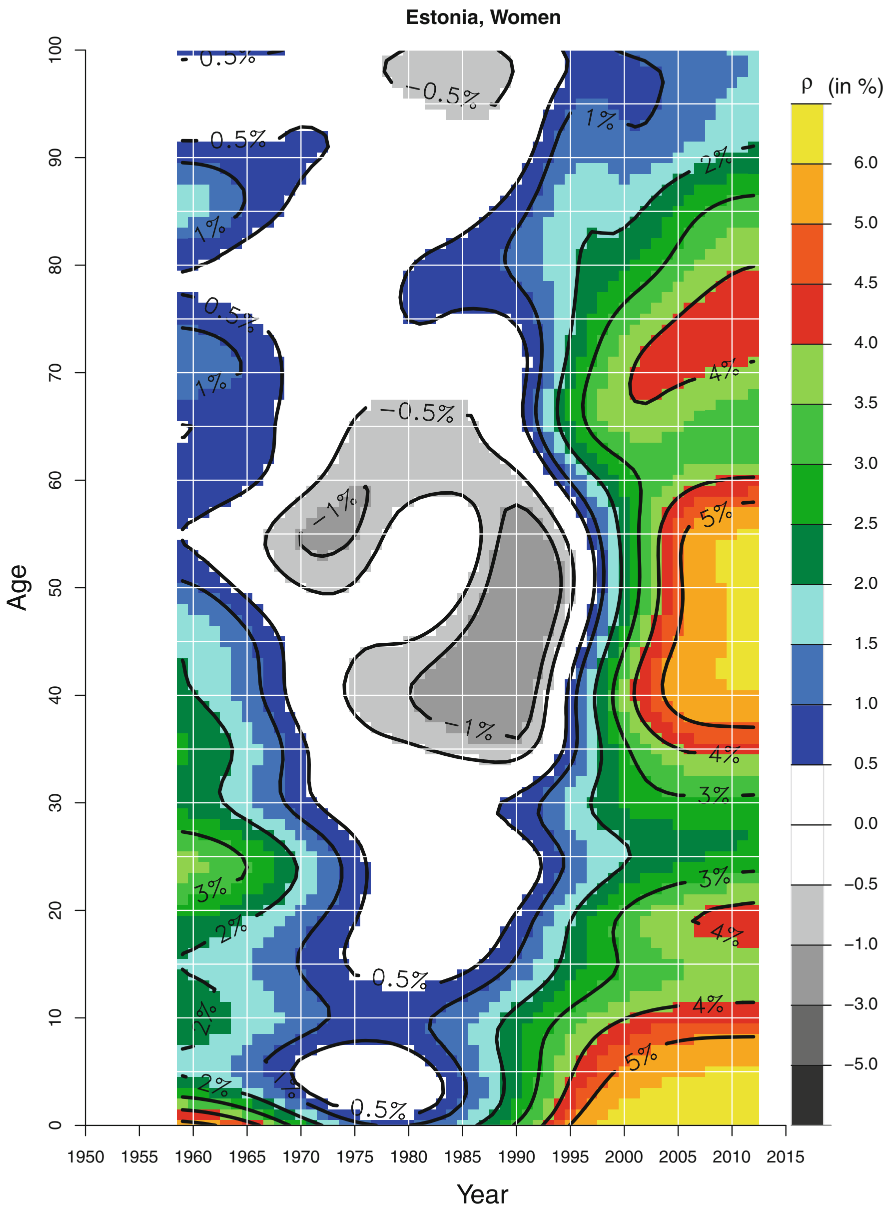

Fig. 6.1 Example of rates of mortality improvement on the Lexis plane: Estonian women aged 0 to 100 years in 1959–2012 (Data source: Human Mortality Database)

in half in less than 20 years.[1] But even at $\rho = 2\%$, which we listed at the threshold from moderate to strong improvements, it requires less than 35 years for a reduction by 50%.

How can we interpret Fig. 6.1, which could be mistaken for a piece of modern art at a first glance? The main shapes appear to be vertical. This implies that mortality changes affected virtually all age groups at the same moment in time—classical period effects. We can also see that white and gray are the dominant colors for females in Estonia for the 1970s and the 1980s. Thus, mortality remained more or less constant during those two decades. During the 1980s at ages 35–60, we can even spot some dark gray areas that correspond to increasing levels of mortality. We can witness a trend reversal approximately in 1990. Within a couple of years, Estonian women at almost all ages experienced remarkable survival improvements. The colors illustrate that mortality dropped by more than 4% for several years at some ages. At such a rapid pace, it takes about 10 years to cut mortality by a third.

6.2 Results

Figures 6.2, 6.3, 6.4, 6.5, 6.6, 6.7, 6.8, 6.9, 6.10, 6.11, 6.12, 6.13, 6.14, 6.15, 6.16, 6.17, 6.18, 6.19, 6.20, and 6.21 (pages 46–65) depict Lexis diagrams of rates of mortality improvements ("ROMIs"), which are the time derivative of age-specific death rates. We argue that those maps are better able to illustrate mortality dynamics than the commonly used "heat maps" of mortality. We plotted our first ROMIs on the Lexis surface about 10 years ago (Rau et al. 2008). In the meantime, those plots have become more commonplace, especially among actuaries, to visualize mortality dynamics. Our method can be considered as a descriptive tool. It is able to detect the predominant dynamics of mortality (or of any other phenomenon measured on the Lexis surface). We think that those "ROMI"-maps provide better insights into mortality dynamics than standard surface maps but are equally intuitively understandable.

During the 1950s, the first years of our observation period, survival improved tremendously especially for infants, children, and young adults. The most remarkable declines in mortality were recorded for Japanese females (Fig. 6.14, page 58). After the end of World War II, life expectancy in Japan was below the average of western European countries. According to data from the Human Mortality Database, life expectancy for Japanese females rose from 60.9 years in 1950 to 72.3 in 1963. Thus, life expectancy increased by almost 1 year within each calendar year during that time span! But also France (Fig. 6.9, p. 53), Italy (Fig. 6.13, p. 57), England & Wales (Fig. 6.7, p. 51) or the United States (Fig. 6.21, p. 65), to name only a few, gained several years of life due to mortality declines at younger ages.

[1] $0.5m(x,t) = m(x,t)e^{\rho\,t}; 0.5 = e^{\rho\,t}; \log_e(0.5) = \rho t; \log_e(0.5)/\rho; \log_e(0.5)/0.035 = -19.80421$.

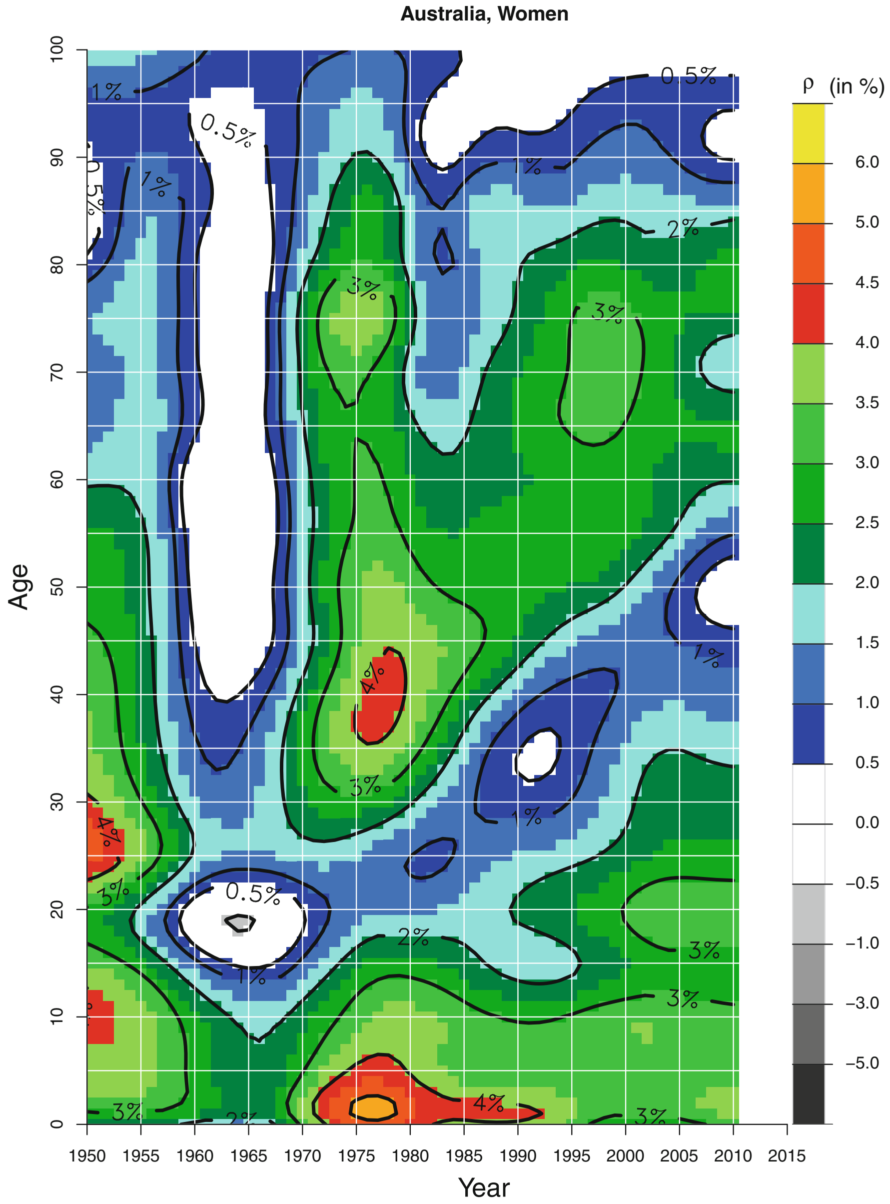

Fig. 6.2 Rates of mortality improvement for women in Australia, 1950–2010 (Data source: Human Mortality Database)

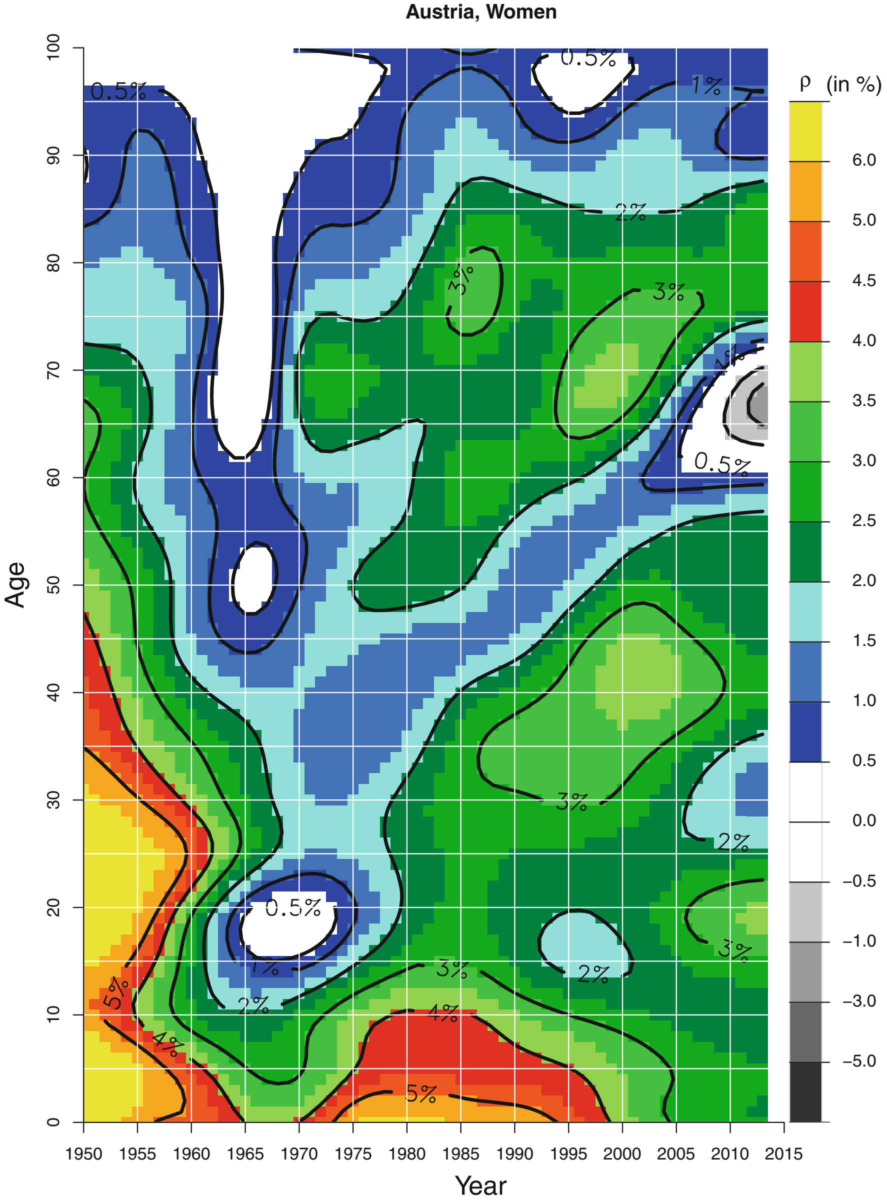

Fig. 6.3 Rates of mortality improvement for women in Austria, 1950–2013 (Data source: Human Mortality Database)

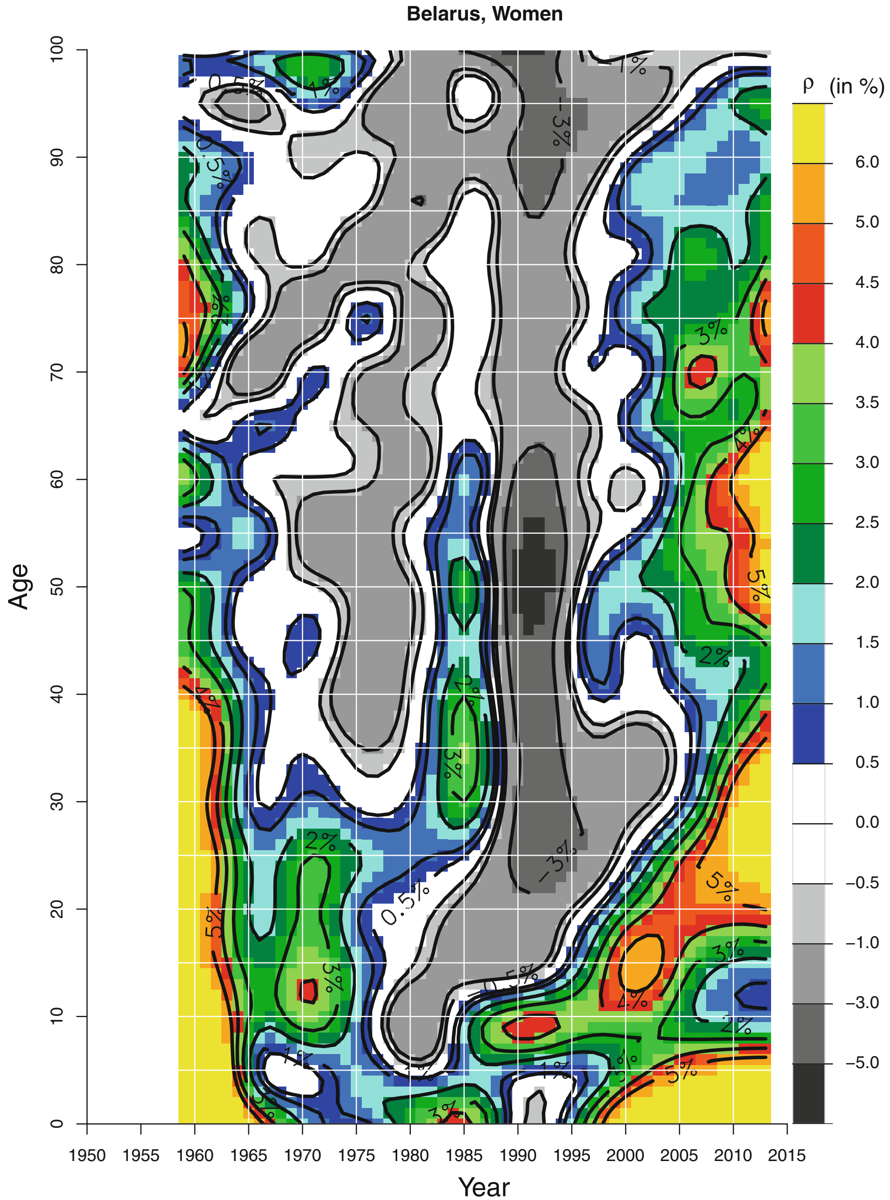

Fig. 6.4 Rates of mortality improvement for women in Belarus, 1950–2013 (Data source: Human Mortality Database)

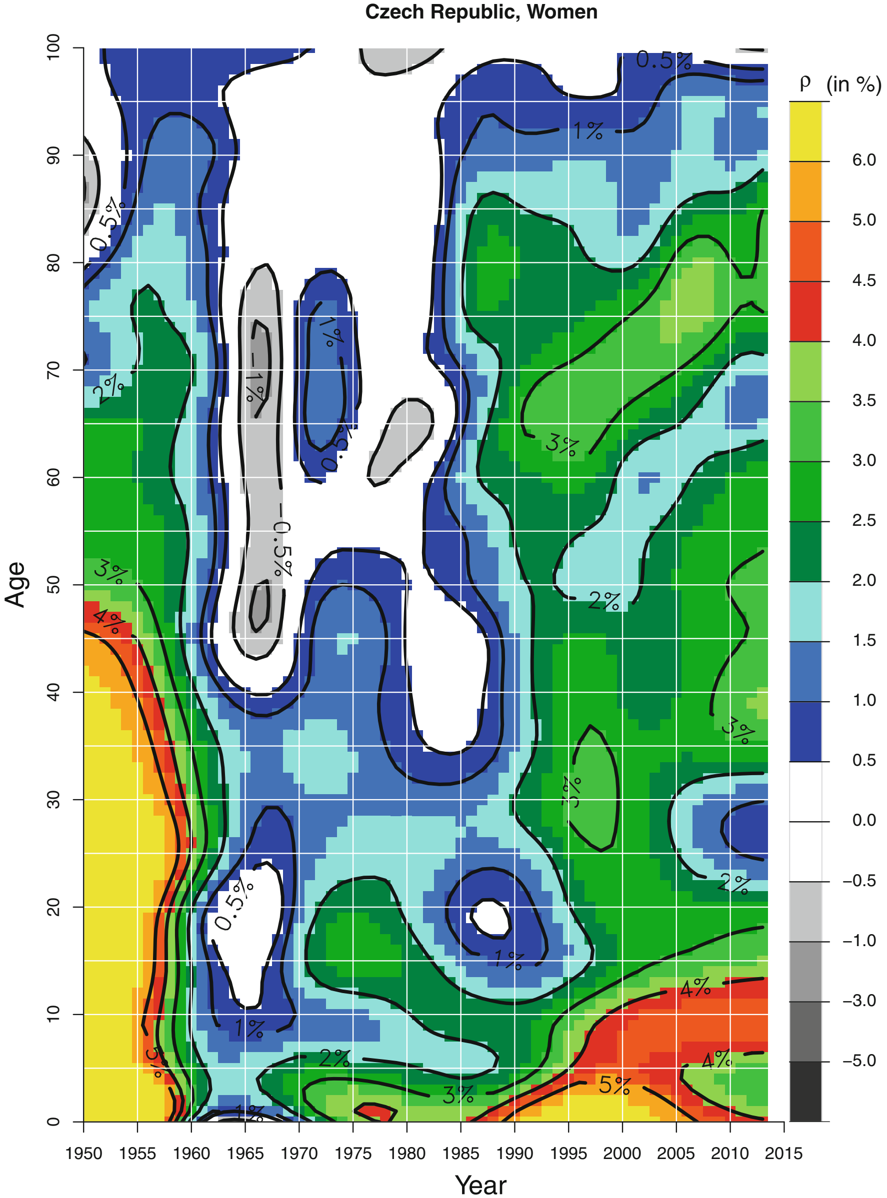

Fig. 6.5 Rates of mortality improvement for women in Czech Republic, 1950–2013 (Data source: Human Mortality Database)

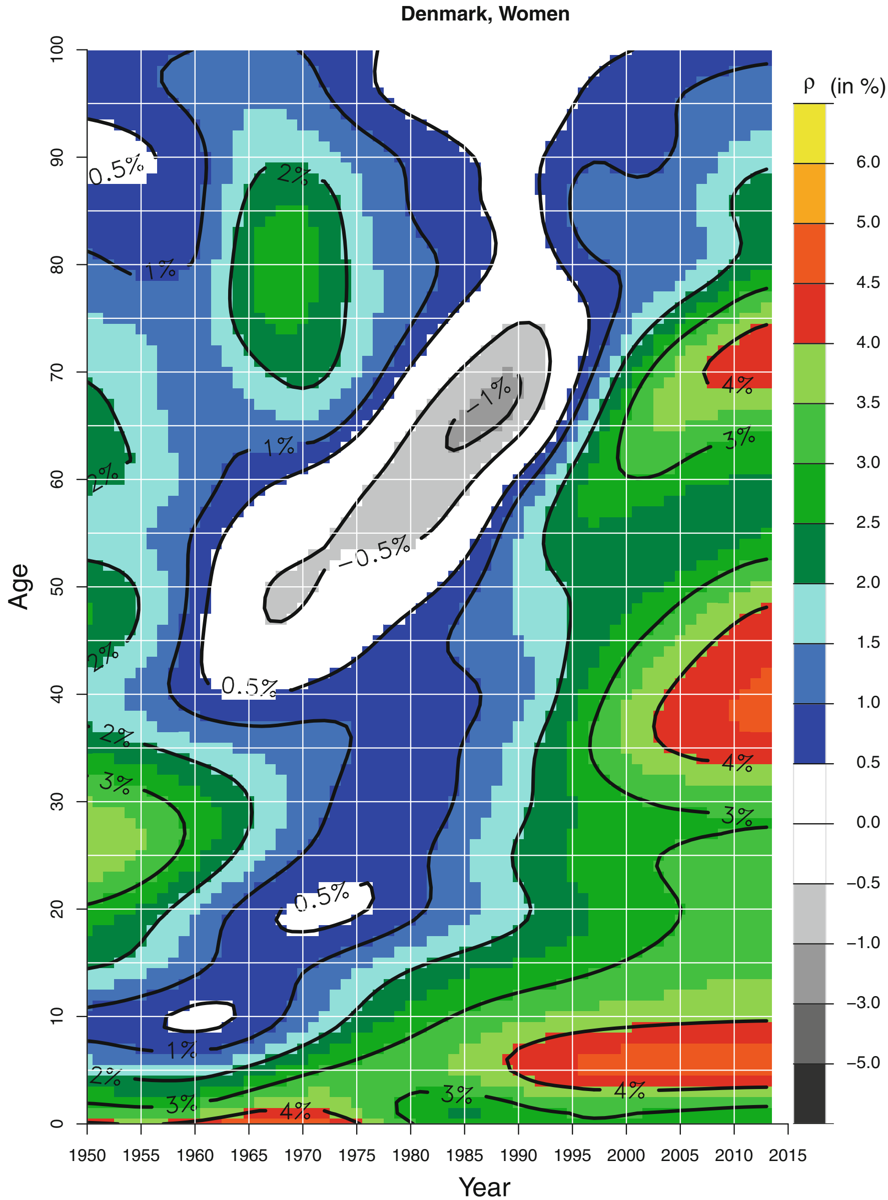

Fig. 6.6 Rates of mortality improvement for women in Denmark, 1950–2013 (Data source: Human Mortality Database)

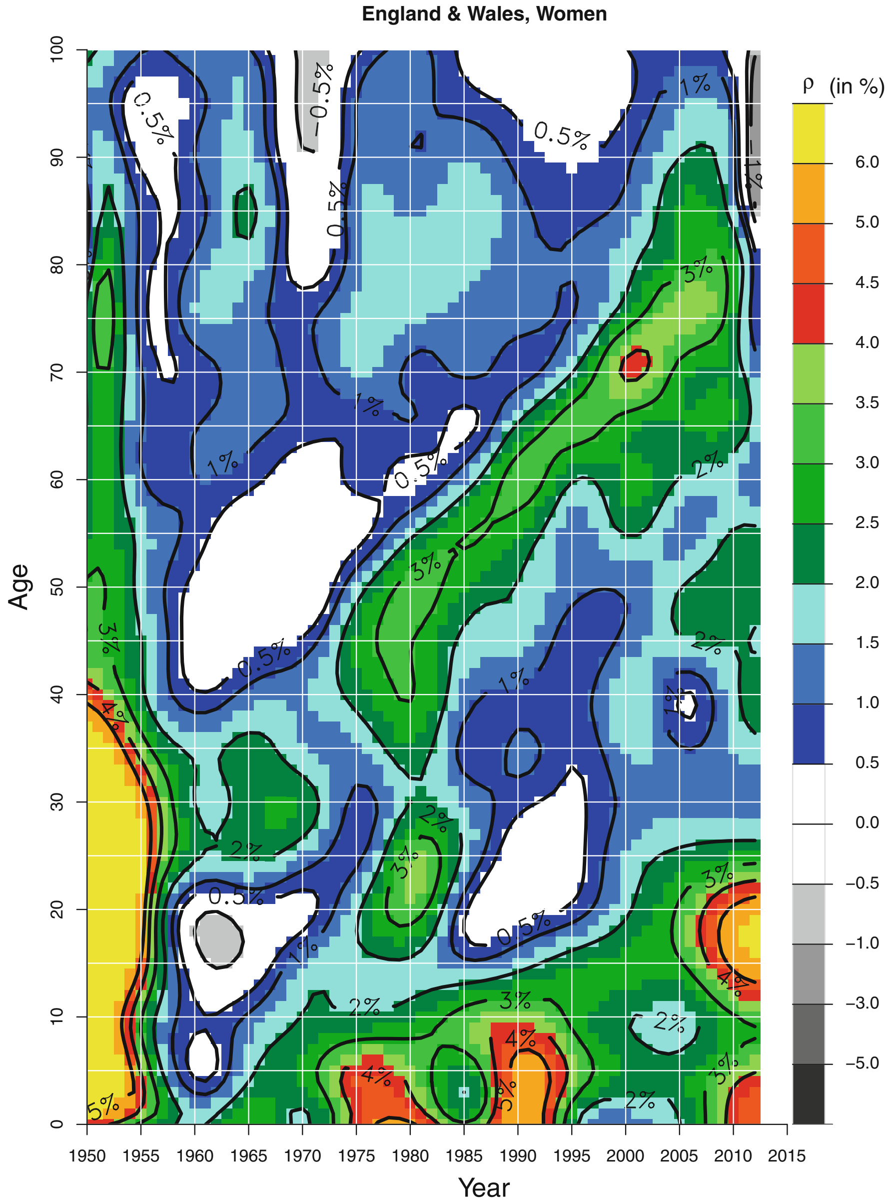

Fig. 6.7 Rates of mortality improvement for women in England & Wales, 1950–2012 (Data source: Human Mortality Database)

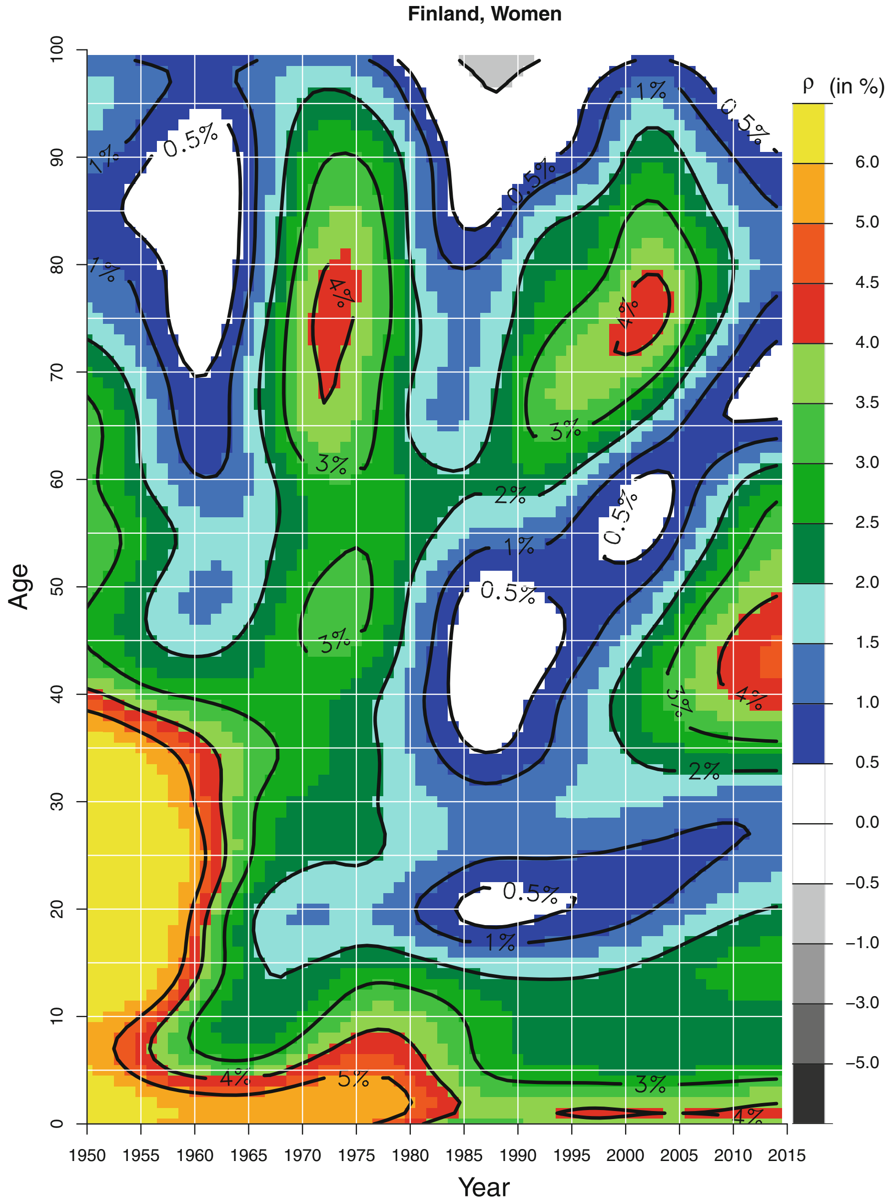

Fig. 6.8 Rates of mortality improvement for women in Finland, 1950–2014 (Data source: Human Mortality Database)

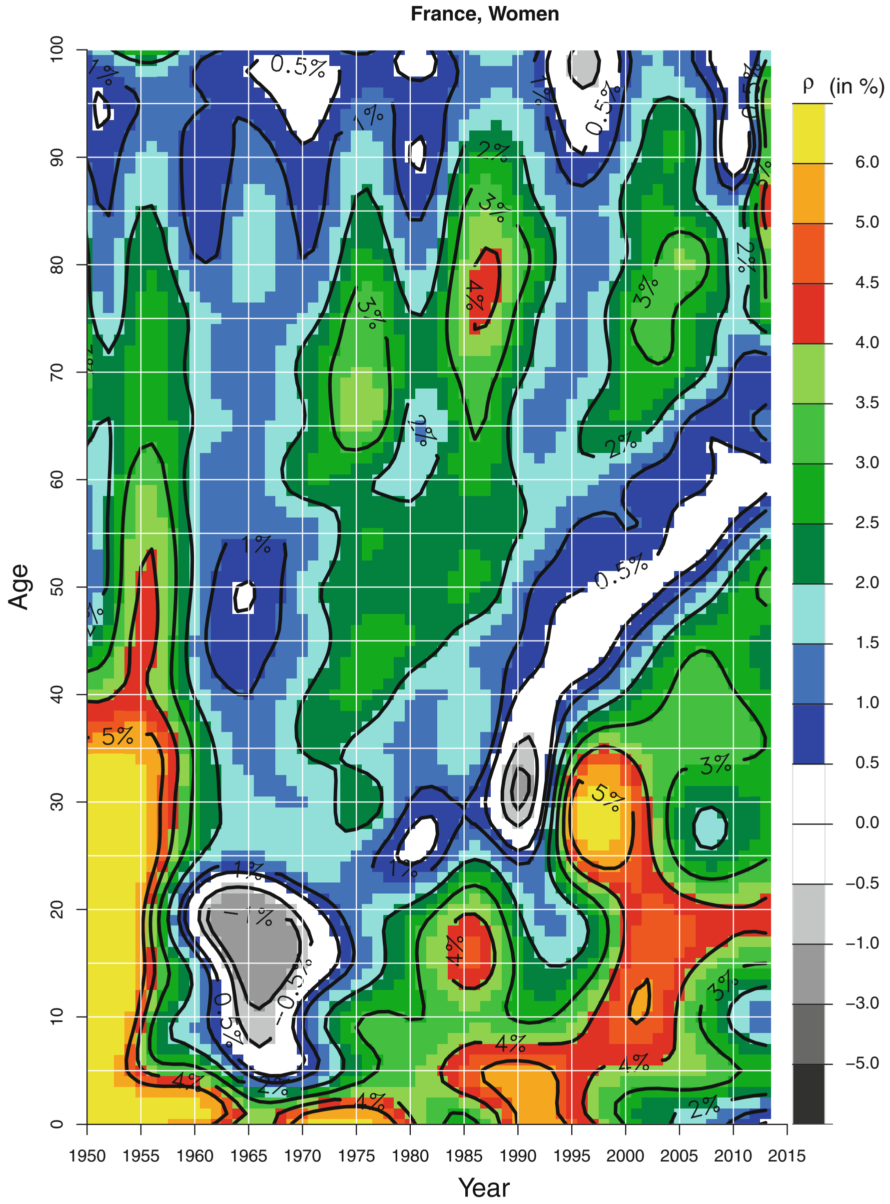

Fig. 6.9 Rates of mortality improvement for women in France, 1950–2013 (Data source: Human Mortality Database)

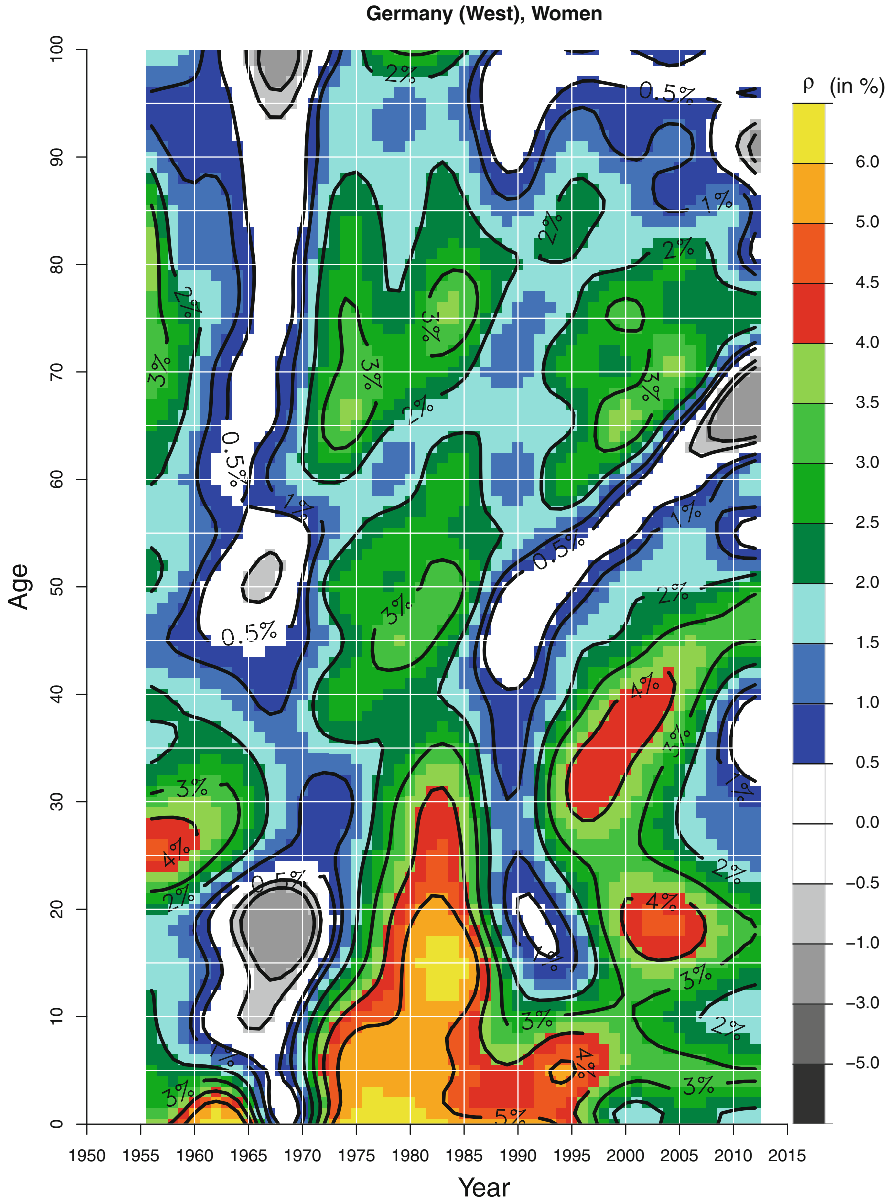

Fig. 6.10 Rates of mortality improvement for women in western Germany, 1956–2012 (Data source: Human Mortality Database)

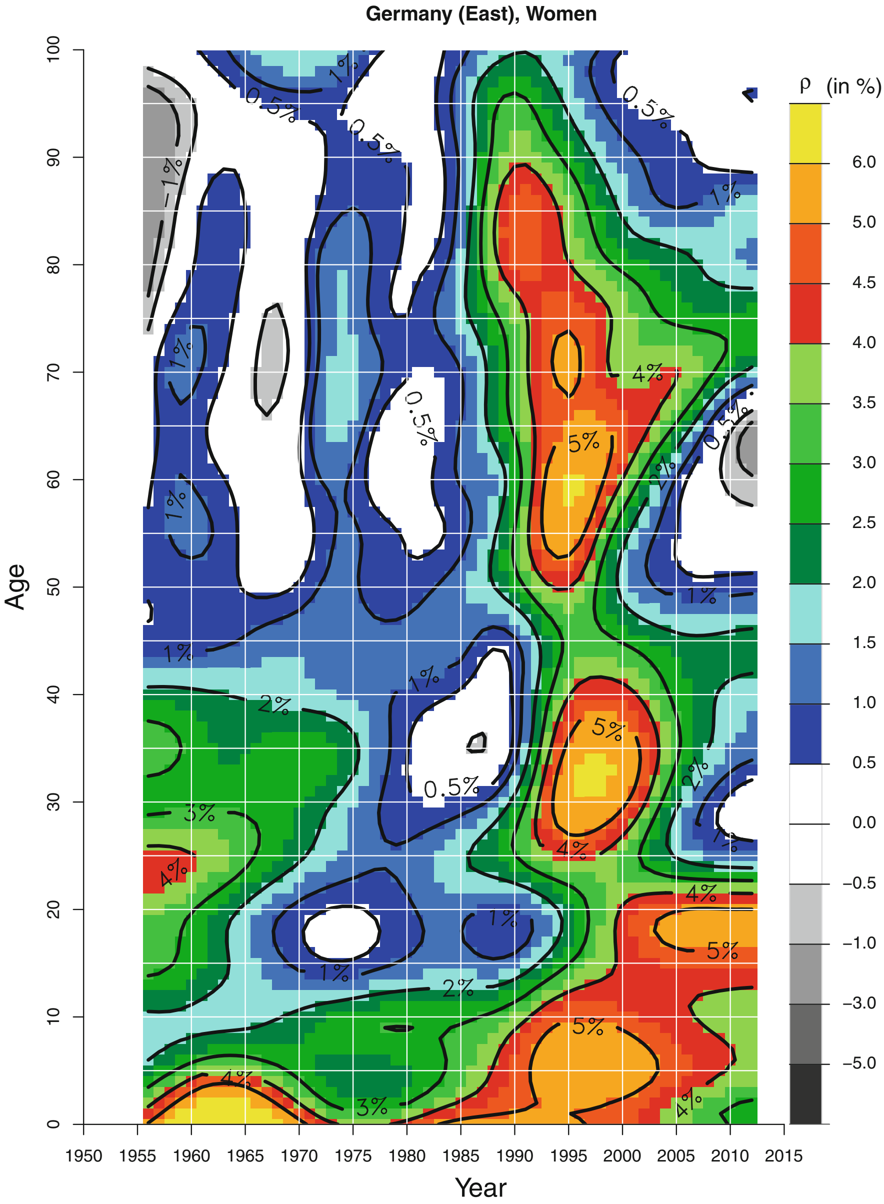

Fig. 6.11 Rates of mortality improvement for women in eastern Germany, 1956–2012 (Data source: Human Mortality Database)

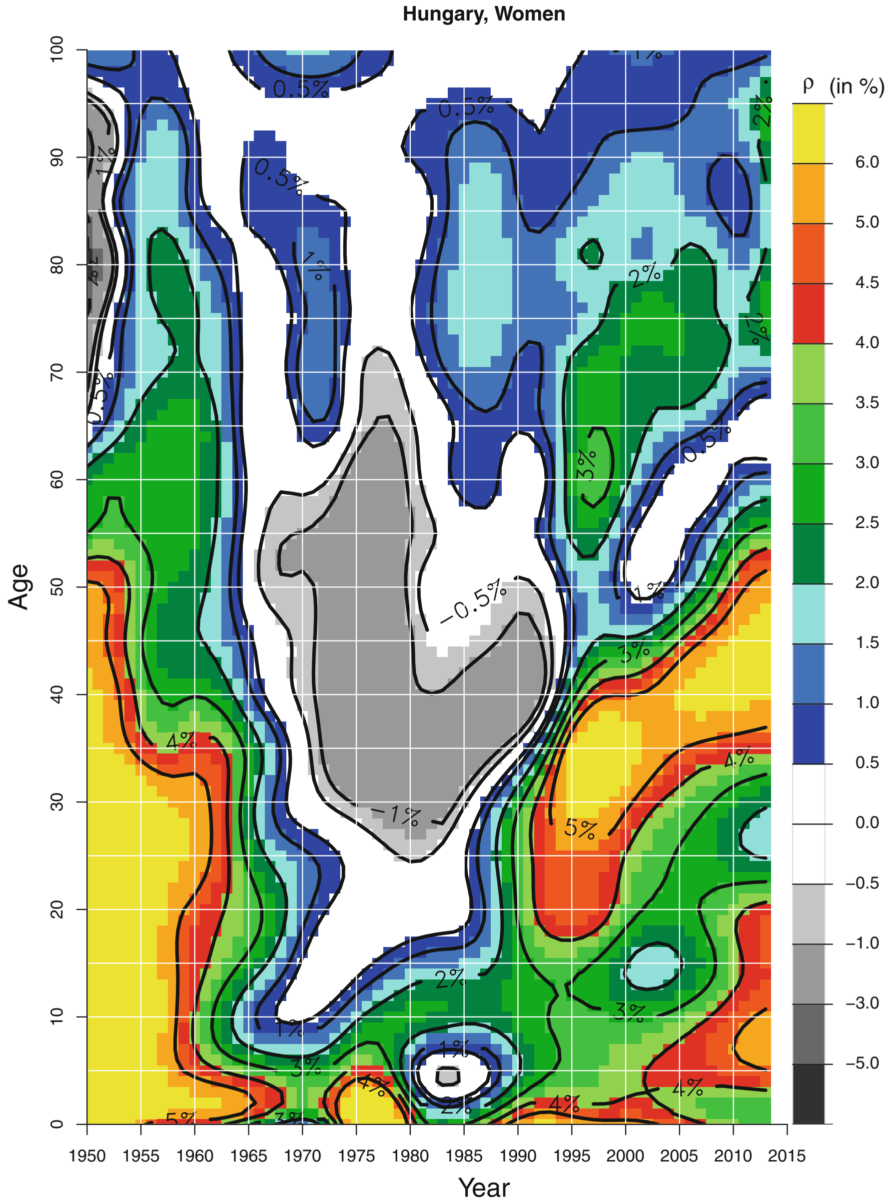

Fig. 6.12 Rates of mortality improvement for women in Hungary, 1950–2013 (Data source: Human Mortality Database)

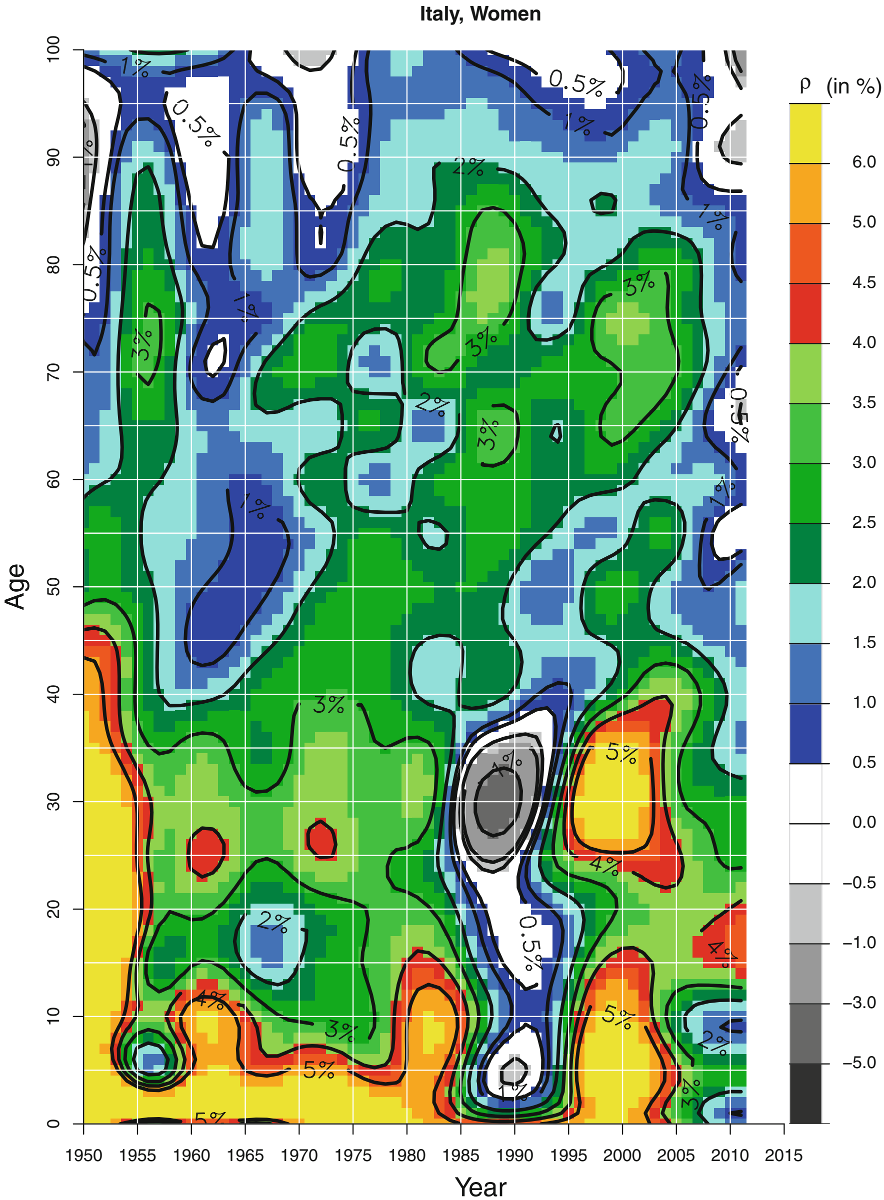

Fig. 6.13 Rates of mortality improvement for women in Italy, 1950–2011 (Data source: Human Mortality Database)

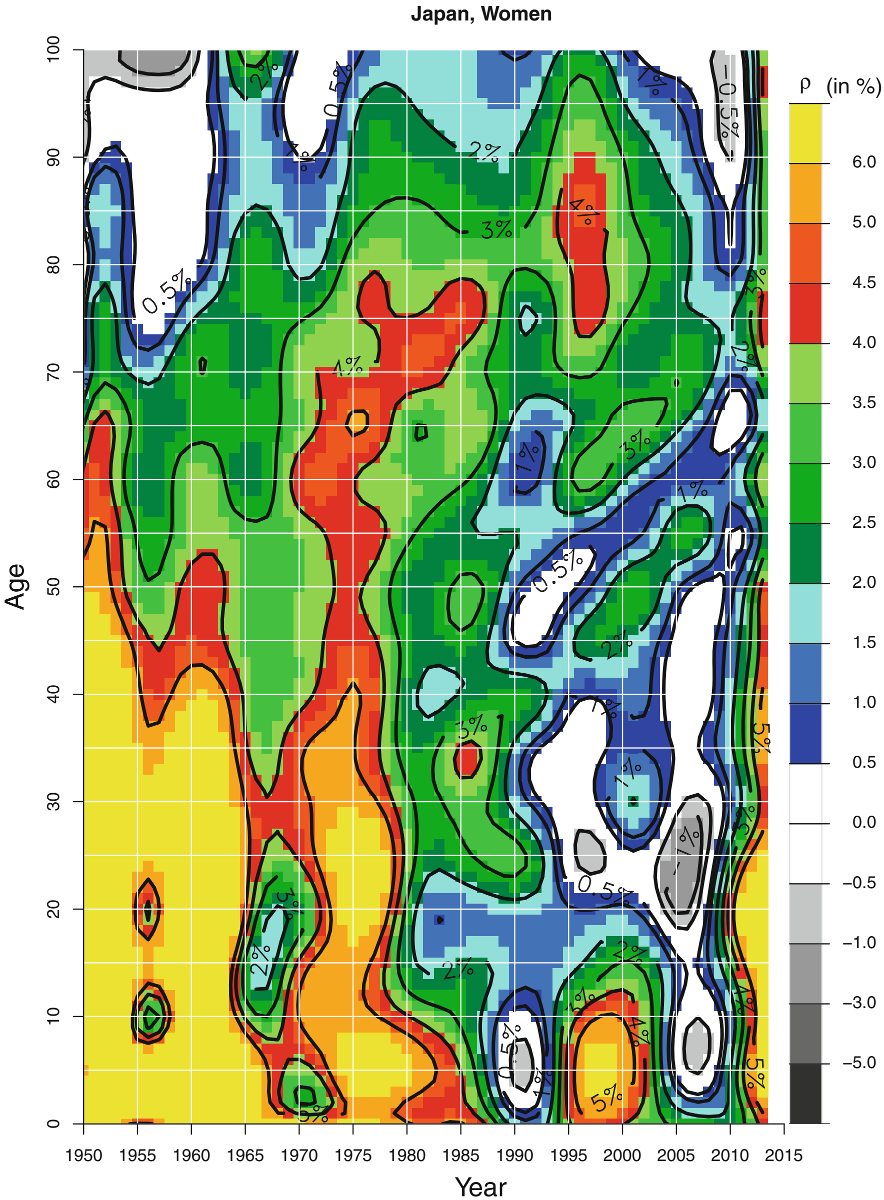

Fig. 6.14 Rates of mortality improvement for women in Japan, 1950–2013 (Data source: Human Mortality Database)

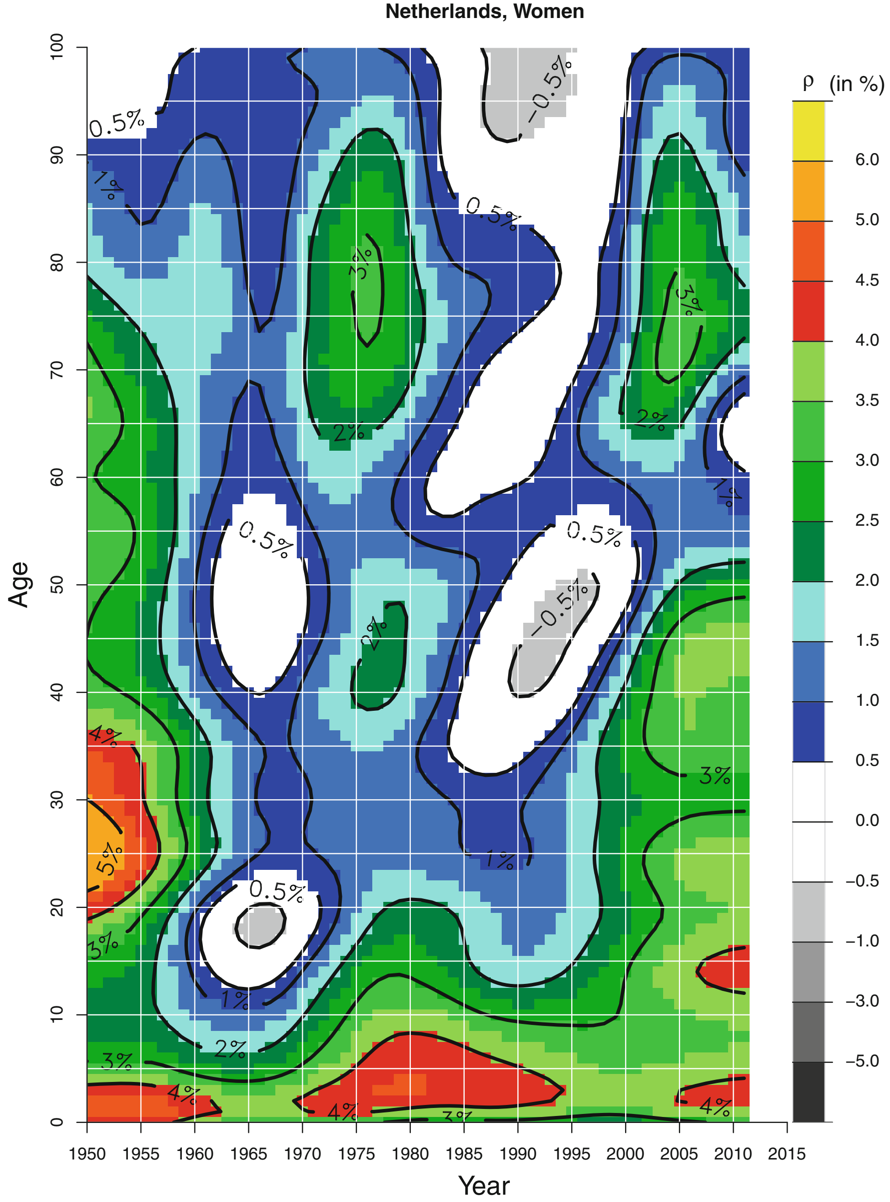

Fig. 6.15 Rates of mortality improvement for women in Netherlands, 1950–2011 (Data source: Human Mortality Database)

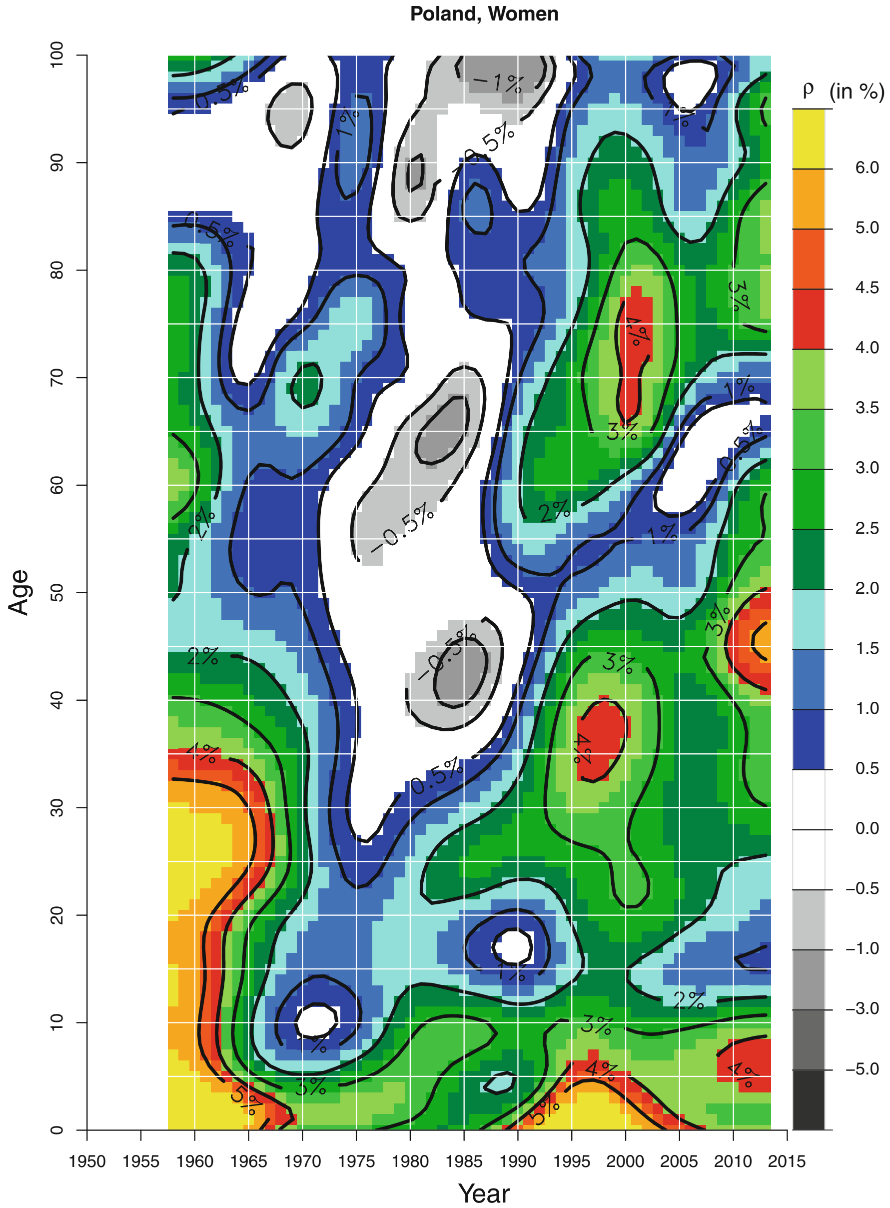

Fig. 6.16 Rates of mortality improvement for women in Poland, 1958–2013 (Data source: Human Mortality Database)

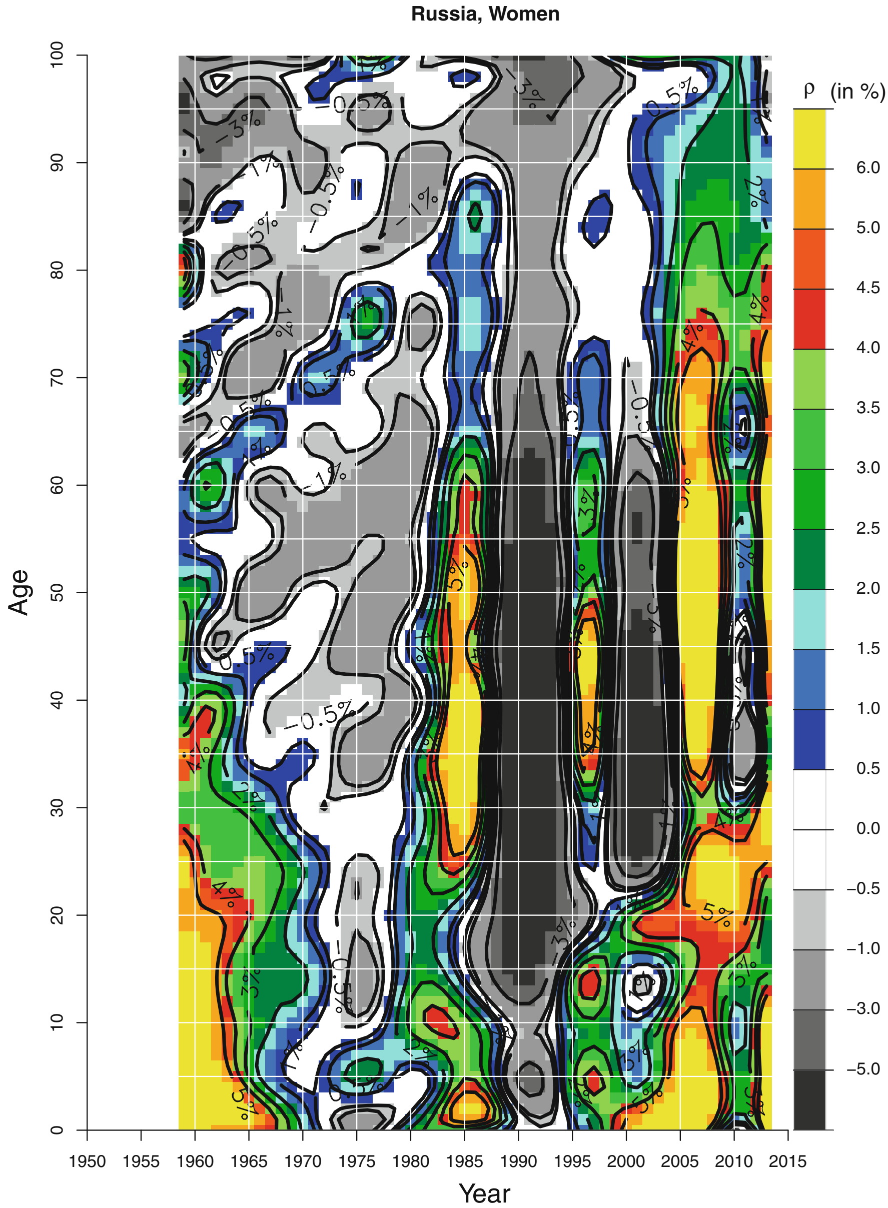

Fig. 6.17 Rates of mortality improvement for women in Russia, 1959–2013 (Data source: Human Mortality Database)

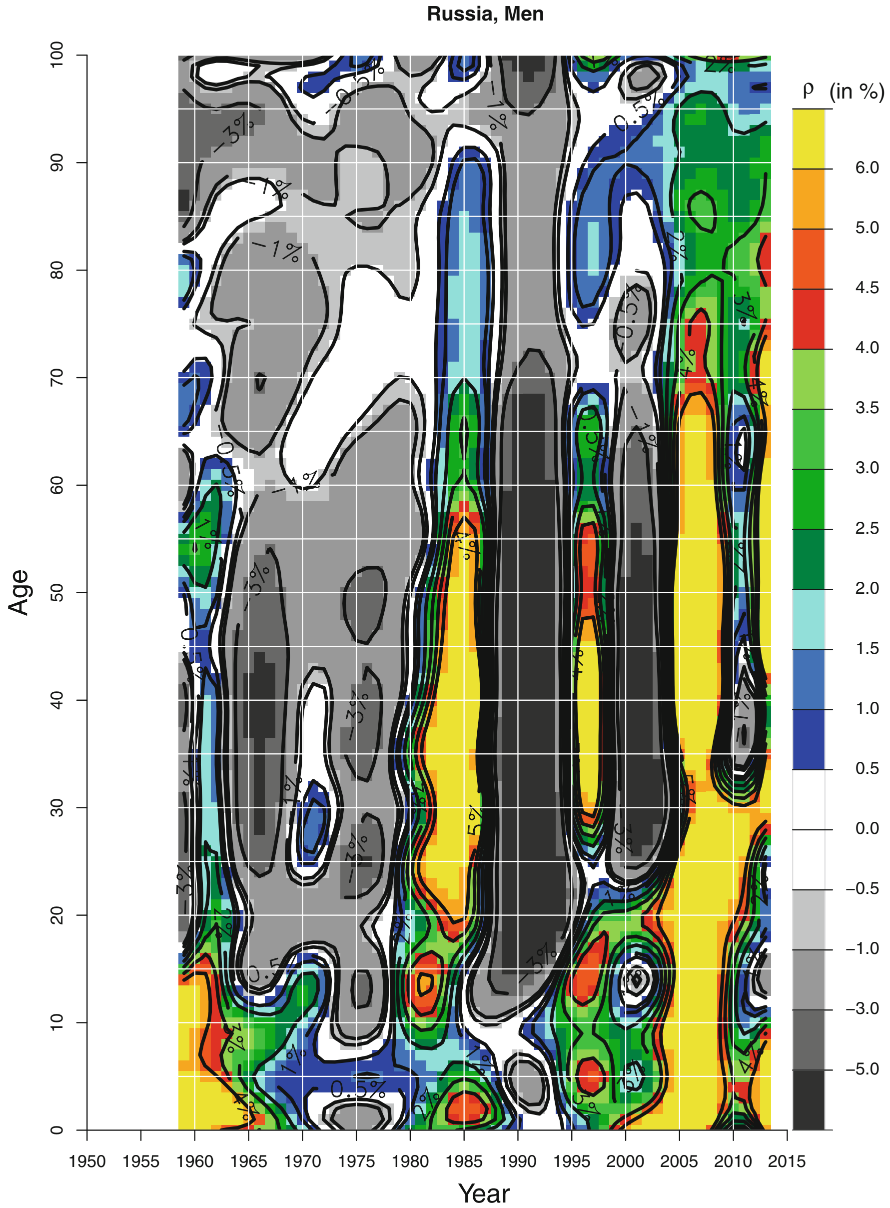

Fig. 6.18 Rates of mortality improvement for men in Russia, 1959–2013 (Data source: Human Mortality Database)

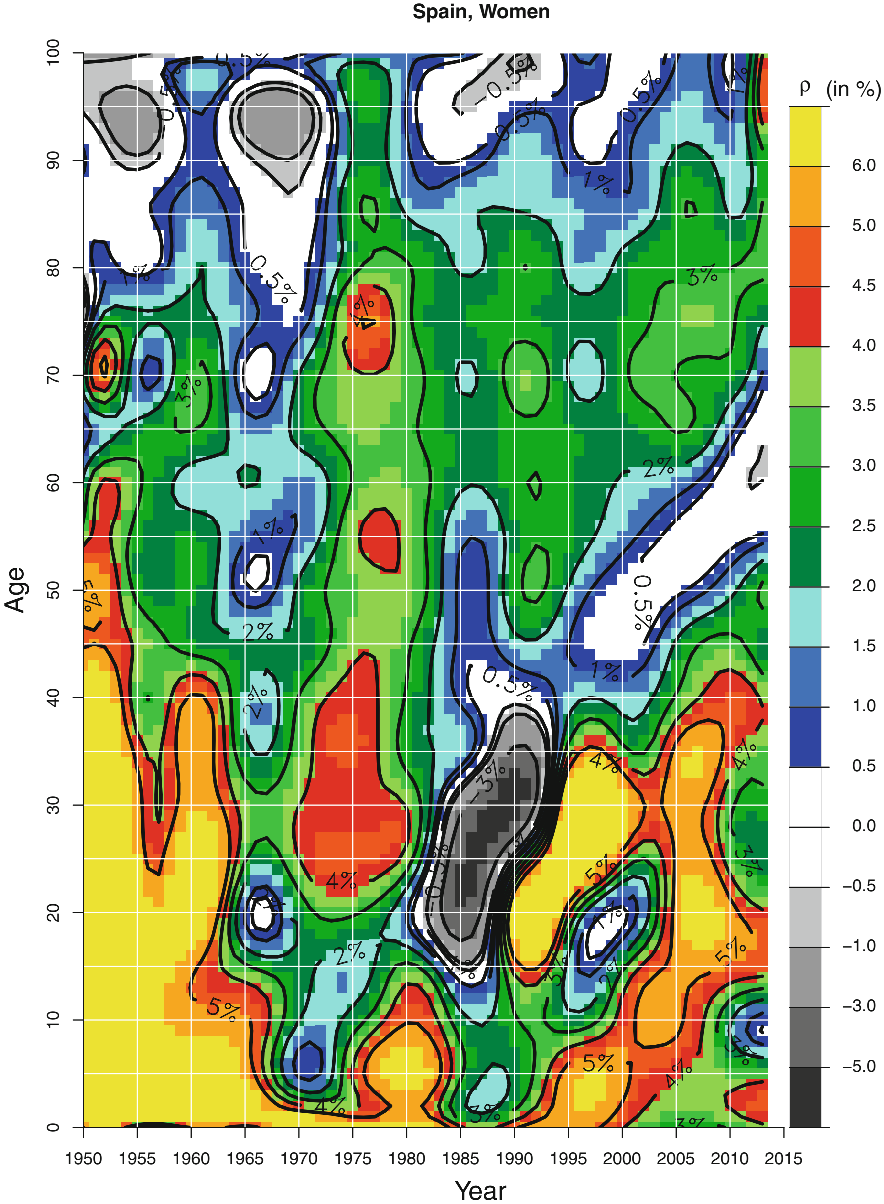

Fig. 6.19 Rates of mortality improvement for women in Spain, 1950–2013 (Data source: Human Mortality Database)

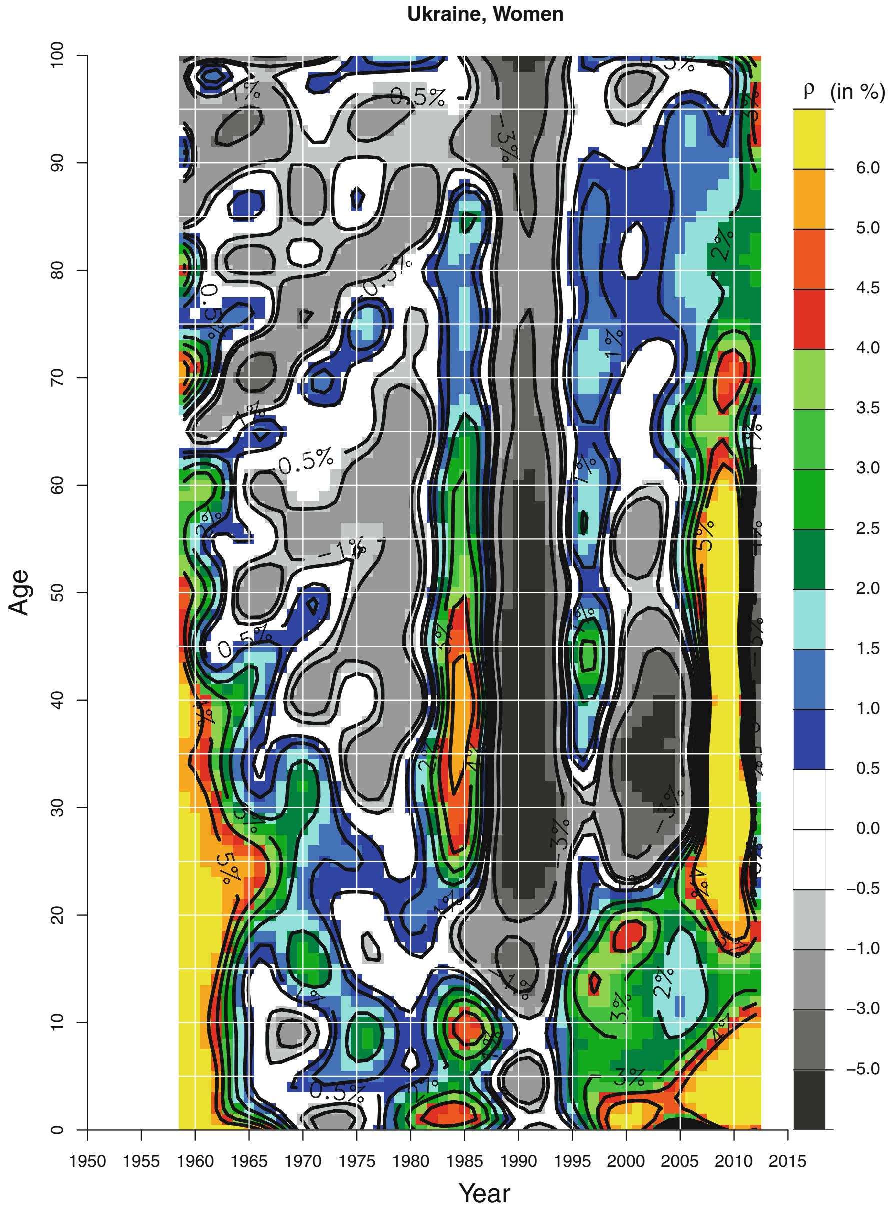

Fig. 6.20 Rates of mortality improvement for women in Ukraine, 1959–2012 (Data source: Human Mortality Database)

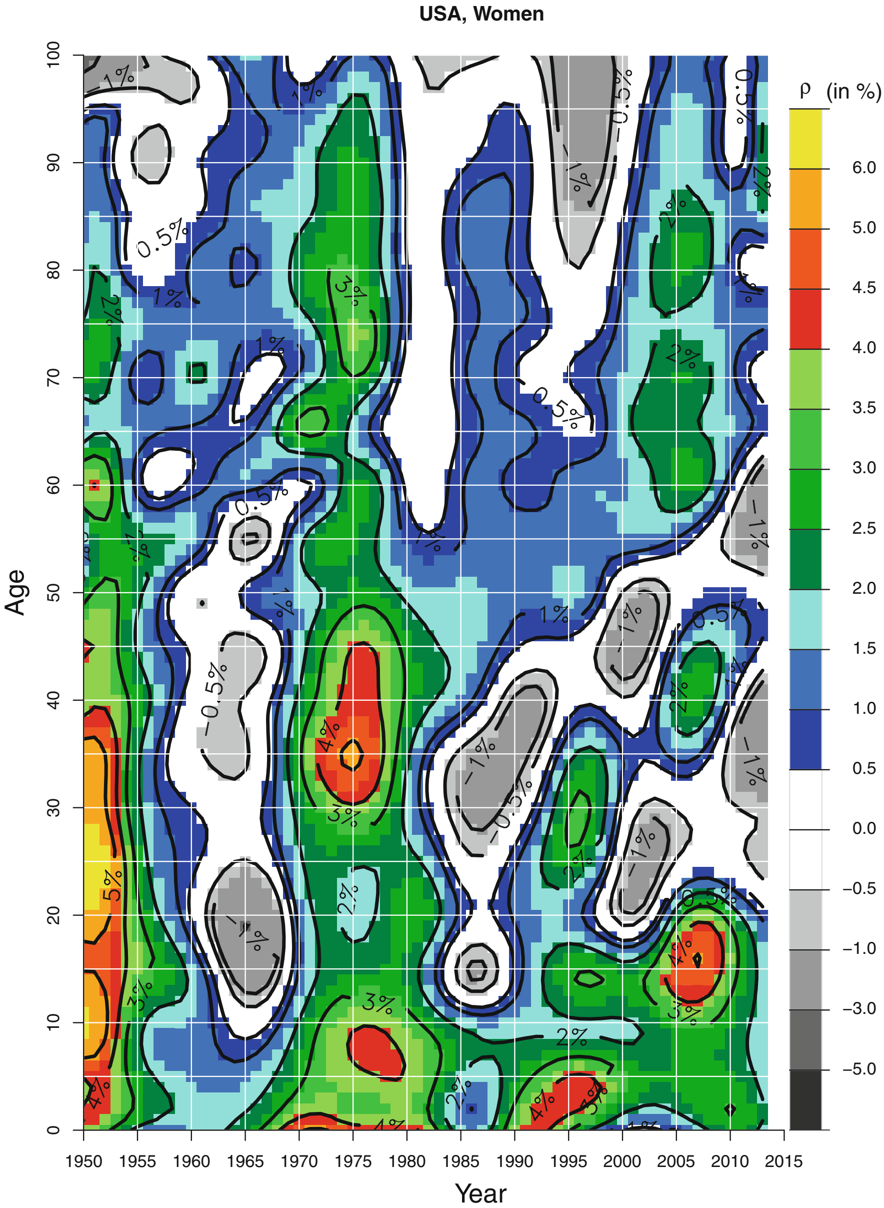

Fig. 6.21 Rates of mortality improvement for women in USA, 1950–2013 (Data source: Human Mortality Database)

Another vertical pattern, suggesting a period effect, can be observed in many countries during the 1970s. Among the countries presented here, Australia (p. 46), Finland (p. 52), western Germany (p. 54), Spain (p. 63) and the United States (p. 65) belong to that group, for instance. We can only speculate that the so-called "cardiovascular revolution" (Meslé and Vallin 2006b) played an important role. It was during the 1970s that medical procedures such as bypass surgery, pace makers to treat cardiovascular diseases were introduced to larger parts of the population. But it was not only the treatment but also the prevention of cardiovascular diseases by drugs such as beta blockers that received a major boost during that time frame.

Many countries that benefited from that period effect during the 1970s exhibit a pattern that resembles a cohort effect in the years thereafter for persons aged approximately 40–80 in the 1970s. It could be argued that those green and red colors along the 45° line that last into the 2000s could be interpreted as a protective effect for those cohorts that benefited first from the new treatment and prevention methods during the 1970s. Please note that this does not imply that subsequent cohorts did not benefit from the advances of the 1970s. This would have resulted in gray cohorts areas. Instead we typically encounter positive developments, just at a smaller scale than the ones of the initial cohorts. This pattern is most visible for Japan (p. 58), Spain (p. 63), Finland (p. 52) and Australia (p. 46), and—to a lesser degree—in France (p. 53) and western Germany (p. 54).

This period effect followed by a cohort effect is not a universal finding, however. Even among western European countries, we detect some outliers. The most prominent example is probably the case of Danish women (p. 50). While the past 20 years or so have shown moderate to strong survival improvements across most of the age range as indicated by the green and red colors, there is one issue that sets Denmark apart from other countries: A cohort effect from the 1960s that lasted well into the early 1990s with stagnating survival, shown in white, or even increasing mortality as suggested by the gray shades. It has been now conclusively shown that Danish women born between the two world wars and their relatively high smoking prevalence are at the root of this cohort effect (e.g., Jacobsen et al. 2002, 2004, 2006; Lindahl-Jacobsen et al. 2016). This cohort effect coincides with relatively minor life expectancy gains among Danish women during that period. Also the United States (p. 65) features a strange pattern. It will be investigated further when we analyze rates of mortality improvement for selected causes of death in Chap. 7.

Similar to the Danish situation, modest life expectancy gains or even losses during the 1970s and 1980s have also been observed in several eastern European countries. But it has not been caused by a cohort effect as the vertical shapes for Hungary (p. 56), the Czech Republic (p. 49), Poland (p. 60) or the former GDR (p. 55) indicate a clear period effect. It can be rather expected that those countries could not (yet) reap the benefits of the cardiovascular revolution that many western countries experienced during that time period. This is supported by the subsequent strong period effects in many of those countries. The most prominent example is probably the former GDR/eastern Germany. When Germany re-unified, there was a difference of almost 3 years among women for life expectancy at birth. Just 15 years later, the difference virtually disappeared for females between the two parts of

Germany. Germany's Federal Health Reporting database (www.gbe-bund.de) can be queried to show that mortality of the circulatory system declined by 47% in eastern Germany between 1990 and 2005.

The most turbulent mortality history during the last 60 years has been probably experienced by Russia and other former Soviet republics (see Figs. 6.4, 6.17, and 6.20 on pages 48, 61, and 64). Since the 1960s, those countries (or then parts of the USSR) have seen sudden changes in mortality spikes and subsequent survival improvements. Those were typically period effects as the vertical patterns in those figures indicate. While we have only focused on mortality of women, we included the case of Russian men in Fig. 6.18 on page 62. There were a few years featuring survival improvements for instance during the mid 1980s, coinciding with Gorbachev's anti-alcohol campaign (Leon et al. 1997), life expectancy of Russian men declined by more than 5 years between 1965 and 2000. France Meslé (2004) points out in her decomposition analysis, that the majority of life years lost was due to increasing mortality from circulatory diseases and violent deaths. Those are precisely the causes, which are mainly responsible for the increase in life expectancy during the first decade of the 2000s: "Our analyses have shown that the recent improvements in life expectancy have mainly been driven by reductions in mortality from circulatory diseases and external causes" (Shkolnikov et al. 2013, p. 930).

The last few years of our observation period provide a mixed result. Life expectancy continued to increase for Russian men, primarily caused by annual survival improvements of more than 3% at ages 70 and above. Mortality declined modestly between ages 40 and 70. And there are some ages between 35 and 40 where mortality increased slightly again. But it is too early to determine whether we see another trend reversal.