**Heat and mortality in New York City since the beginning of the 20th century**

*eAppendix*

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***R Code for main analysis***

# LOAD PACKAGES

library(dlnm) ; library(splines) ; library(mvmeta)

# LOAD THE RAW DATA FOR SELECTED YEARS

rawdata <- subset(read.csv(file="NYC.csv"),

year%in%c(1900:1948,1973:2006))

# CREATE THE DATASET

data <- data.frame(

date = with(rawdata,as.Date(paste(year,month,day,sep="-"))),

year = rawdata$year,

month = rawdata$month,

day = rawdata$day,

dow = weekdays(with(rawdata,as.Date(paste(year,month,day,sep="-"))),abbr=T),

doy = as.numeric(format(with(rawdata,as.Date(paste(year,month,day,sep="-"))),"%j")),

death = rawdata$totalover15,

tmean = with(rawdata,((tmax-32)\*5/9 + (tmin-32)\*5/9)/2)

)

# CREATE DECADES

declow <- 1900+c(0,10,20,30,40,73,80,90,100)

dechigh <- 1900+c(9,19,29,39,48,79,89,99,106)

decadelab1 <- paste(declow,dechigh,sep=" - ")

decadelab2 <- paste(1900+c(0:4,7:10)\*10,"s",sep="")

data$decade <- cut(data$year,breaks=1900+c(0:4,7:11)\*10,

labels=decadelab2,right=F)

# RESTRICT TO SUMMER MONTHS

datasum <- subset(data, month%in%6:9)

#############################################################################

# REGRESSION MODELS

# CREATE A LIST OF PREDICTION FROM DLNM FOR EACH DECADE

predlist <- lapply(levels(datasum$decade), function(sub) {

# SELECT DATA

datadec <- datasum[datasum$decade==sub,]

range <- c(ceiling(min(datadec$tmean,na.rm=T)),

floor(max(datadec$tmean,na.rm=T)))

# CREATE THE CROSS-BASIS FOR A SEASONAL ANALYSIS:

# - QUADRATIC SPLINE WITH 4 DF (TWO EQUALLY SPACED KNOTS) FOR TEMPERATURE

# - NATURAL SPLINE WITH 4 DF (2 KNOTS IN LOG SCALE) FOR LAG

varknots <- equalknots(datadec$tmean,fun="bs",degree=2,df=4)

lagknots <- logknots(5,fun="ns",df=4)

cb <- crossbasis(datadec$tmean,lag=5,argvar=list(fun="bs",degree=2,

knots=varknots,cen=22),arglag=list(knots=lagknots),group=datadec$year)

# RUN THE MODEL

model <- glm(death ~ cb+dow+ns(doy,4)+ns(year,2),family=quasipoisson(),datadec)

# RETURN THE PREDICTION

return(crosspred(cb,model,at=range[1]:range[2],bylag=0.2))

})

names(predlist) <- decadelab2

#############################################################################

# COMPARISON BETWEEN PERIODS AND TEST ON TREND

# CREATE VECTOR OF ESTIMATES AND VARIANCES

est <- sapply(predlist,function(x) x$allfit["29"])

var <- sapply(predlist,function(x) x$allse["29"])^2

# CREATE META-VARIABLE WITH PERIODS AND TREND

period <- factor(rep(c("1900-1948","1973-2006"),c(5,4)))

trend <- seq(period)

# COMPARE PERIODS

meta1 <- mvmeta(est~period,var)

summary(meta1)

newdata <- data.frame(period=unique(period),row.names=unique(period))

exp(predict(meta1,newdata,ci=T))

# TEST ON TREND (ONLY SECOND PERIOD)

meta2 <- mvmeta(est~trend,var,subset=period=="1973-2006")

summary(meta2)

exp(predict(meta2,ci=T))

(1-exp(coef(meta2)[2]))\*100

(1-exp(coef(meta2)[2]+1.96\*sqrt(vcov(meta2)[2,2])))\*100

(1-exp(coef(meta2)[2]-1.96\*sqrt(vcov(meta2)[2,2])))\*100

############################################################################

# TABLES

# TABLE 1

tab1 <- cbind(

mean = tapply(data$tmean,data$decade,mean,na.rm=T),

"90th" = tapply(data$tmean,data$decade,quantile,0.9,na.rm=T),

"95th" = tapply(data$tmean,data$decade,quantile,0.95,na.rm=T),

"99th" = tapply(data$tmean,data$decade,quantile,0.99,na.rm=T)

)

format(tab1,digits=3)

# TABLE 2 (FOR ALL-CAUSE MORTALITY ONLY)

tab2 <- t(sapply(predlist, function(x) with(x,cbind(allRRfit,allRRlow,

allRRhigh)[as.character("29"),])))

colnames(tab2) <- c("Est","95%CIlow","95%CIhigh")

format(tab2,digits=3)

#############################################################################

# FIGURES

col <- rev(rainbow(length(predlist)))

# FIGURE 1

pdf("fig1.pdf",width=5,height=4)

layout(1)

par(mar=c(4.5,4,1,1))

plot(predlist[[1]],"overall",type="n",ci="n",col=1,ylim=c(0.8,4),xlim=c(5,35),

lwd=1.5,ylab="Relative Risk",xlab="Mean Temperature (°C)")

for(i in seq(predlist)) lines(predlist[[i]],col=col[i])

legend("topleft",decadelab2,col=col,lwd=1.5,bty="n",cex=0.7,ncol=3)

dev.off()

# FIGURE 2

pdf("fig2.pdf",width=5,height=4)

layout(1)

par(mar=c(4.5,4,1,1))

plot(predlist[[1]],var=29,type="n",ci="n",col=1,ylim=c(0.9,1.3),

ylab="Relative Risk",xlab="Lag (Days)")

for(i in seq(predlist)) lines(predlist[[i]],var=29,col=col[i])

legend("topright",decadelab2,col=col,lwd=1.5,bty="n",cex=0.7,ncol=3)

dev.off()

# FIGURE 3

pdf("fig3.pdf",width=8,height=5)

par(mar=c(4,4,1,2))

layout(1)

plot(1:12,seq(1,1.5,length=12),type="n",xaxt="n",xlab="Decade",

ylab="Cumulative Relative Risk at 29°C vs 22°C",frame.plot=F)

axis(1,at=1:12,labels=F)

axis(1,at=1:11+0.5,labels=paste(1900+0:10\*10,"s",sep=""),tick=F,cex.axis=0.8)

seqdec <- c(1:5,8:11)+0.5

for(i in seq(predlist)) {

points(seqdec[i],predlist[[i]]$allRRfit["29"],pch=19,cex=1.3)

arrows(seqdec[i],predlist[[i]]$allRRlow["29"],seqdec[i],

predlist[[i]]$allRRhigh["29"],code=3,angle=90,length=0.03,lwd=1)

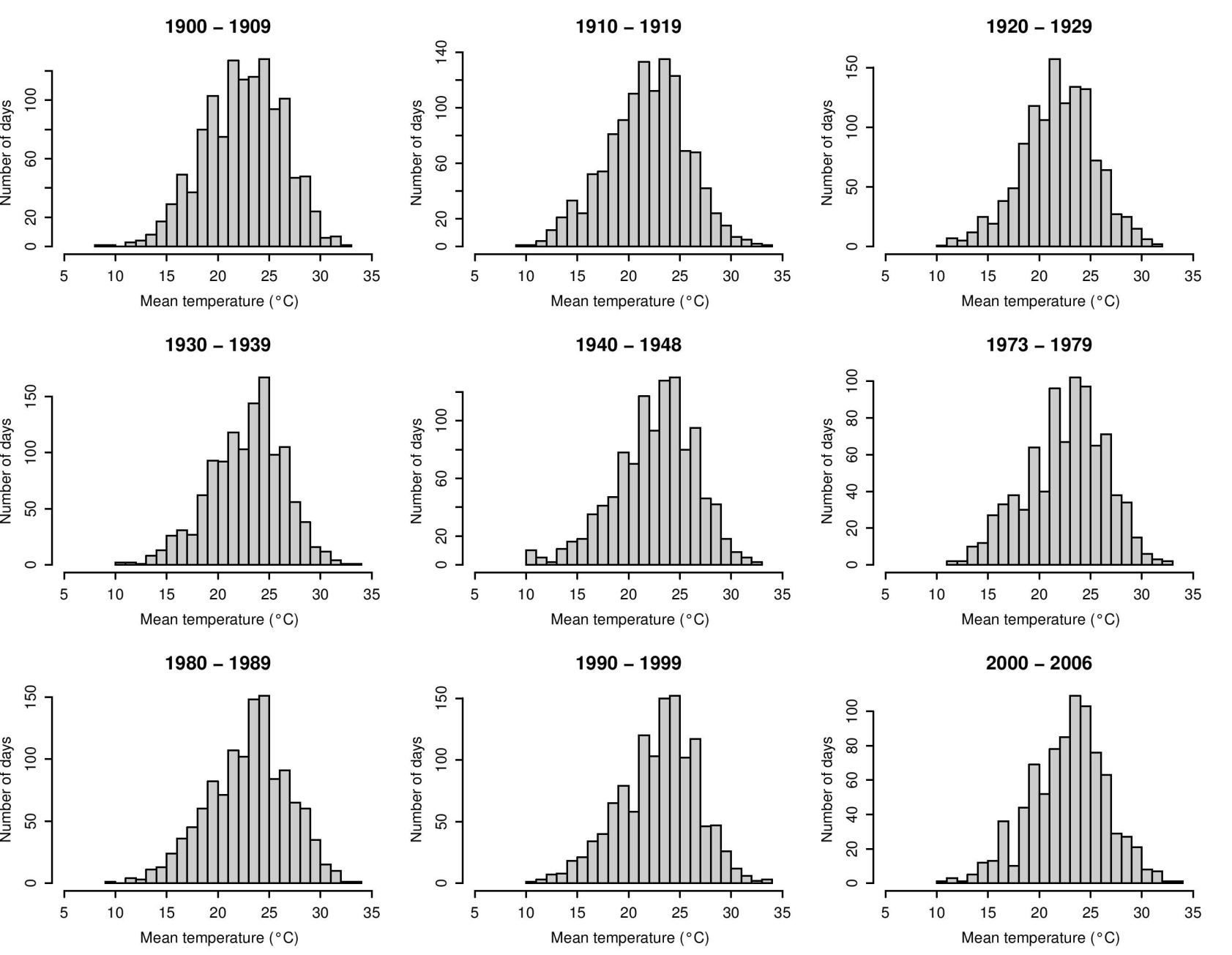
}

abline(h=1)

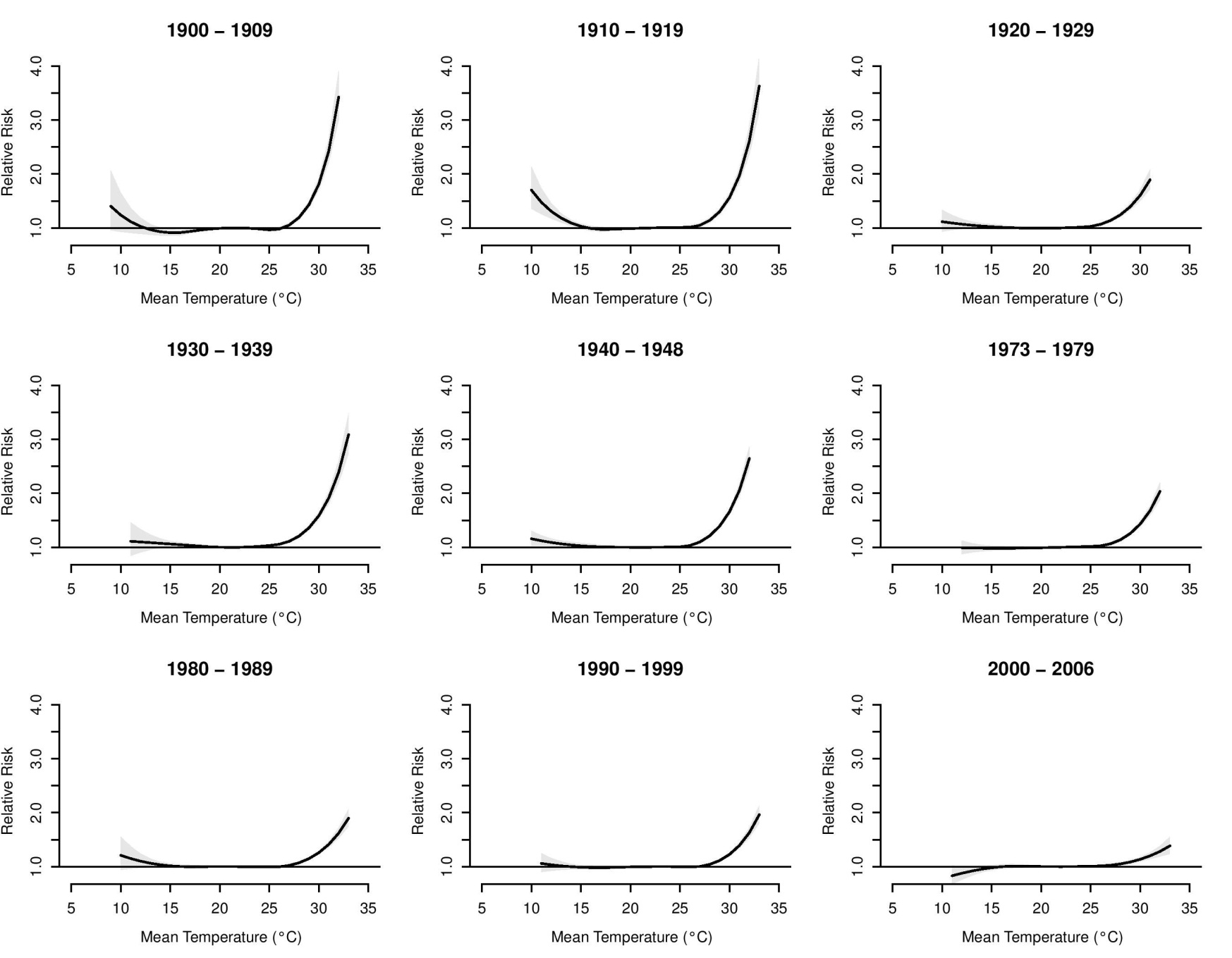
dev.off()

#

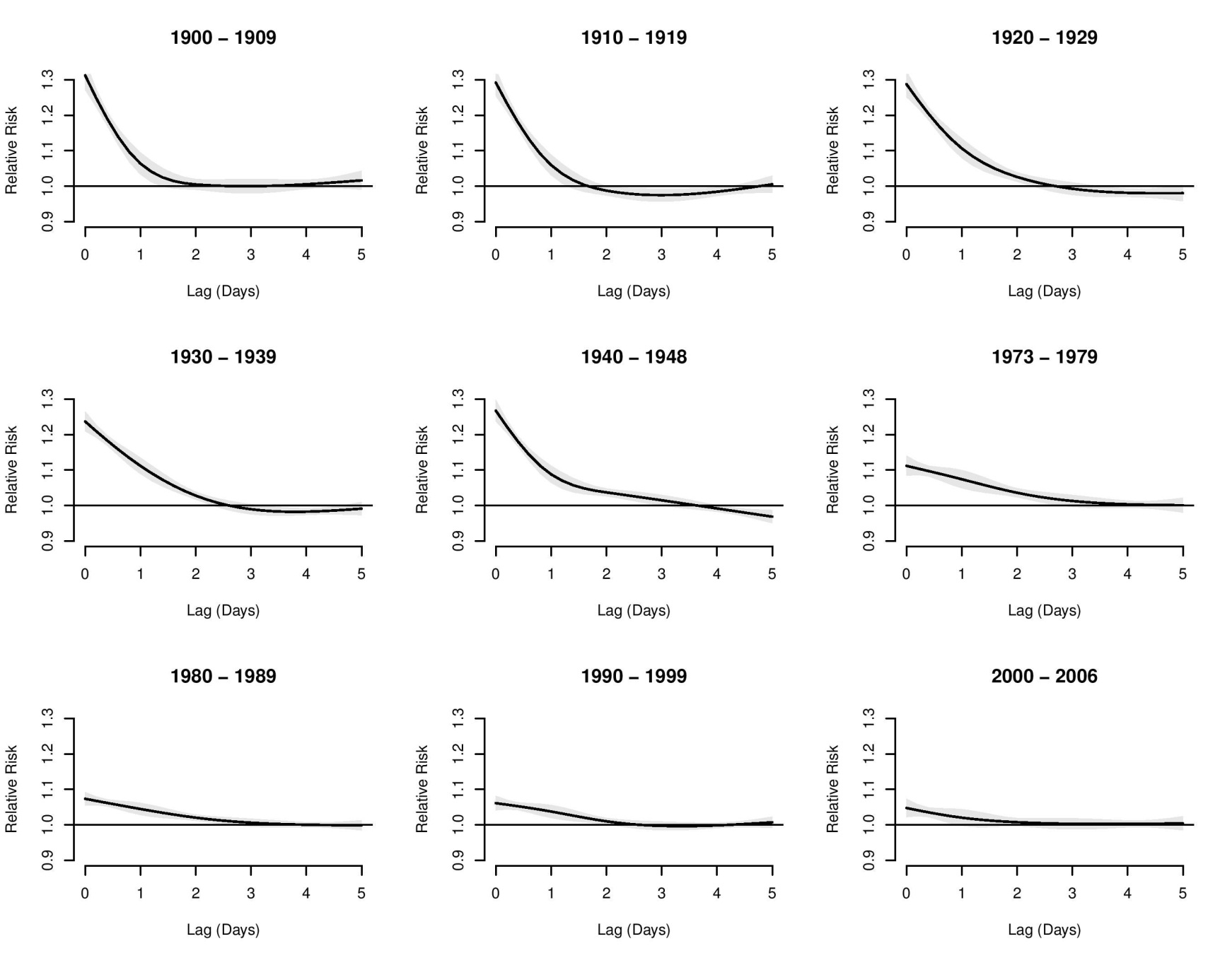
***eFigures***

*eFigure 1* Mean summer temperature histograms for New York City by decade, 1900s-2000s 

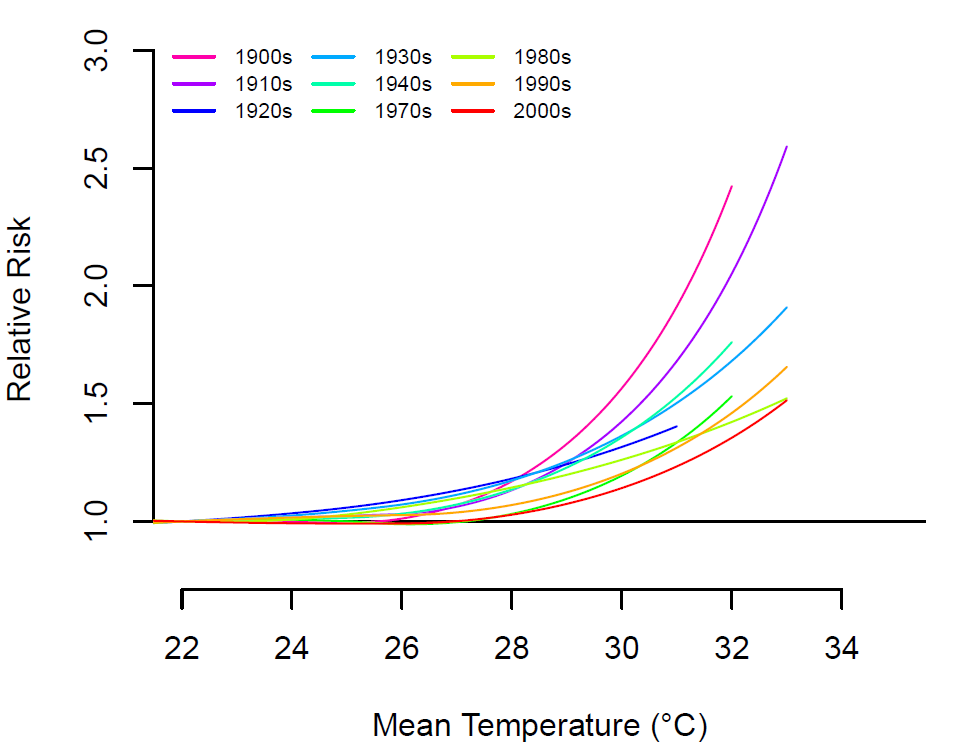
*eFigure 2* Temperature – mortality curves of overall cumulative relative risk for New York City by decade, 1900s -2000s (separate plots). Calculated using a distributed lag non-linear model with a quadratic spline with 4 degrees of freedom for the temperature and a natural cubic spline with 4 degrees of freedom for the lag and 22°C as a reference temperature.



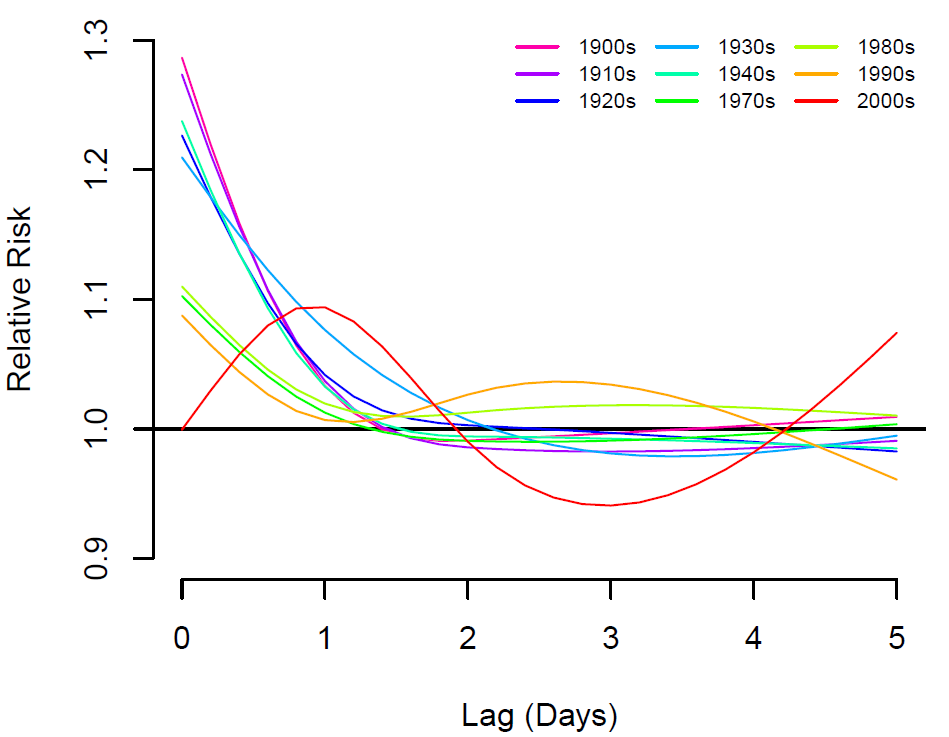
*eFigure 3* Lagged relative risks at 29°C relative to 22°C by decade, 1900s-2000s (separate charts). Calculated using a distributed lag non-linear model with a quadratic spline with 4 degrees of freedom for the temperature and a natural cubic spline with 4 degrees of freedom for the lag.



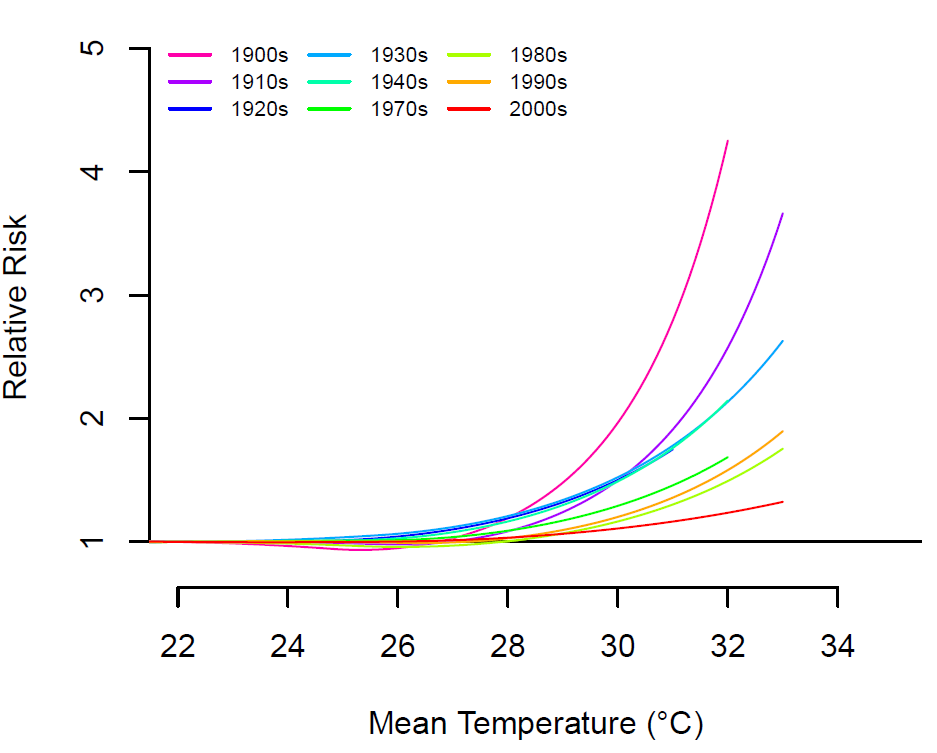
*eFigure 4* Temperature – mortality curves of overall cumulative risk for New York City by decade, 1900s -2000s for the15-44 age group. Calculated using a distributed lag non-linear model with a quadratic spline with 4 degrees of freedom for the temperature and a natural cubic spline with 4 degrees of freedom for the lag and 22°C (corresponding to approximately the 80th percentile of annual temperature) as a reference temperature.



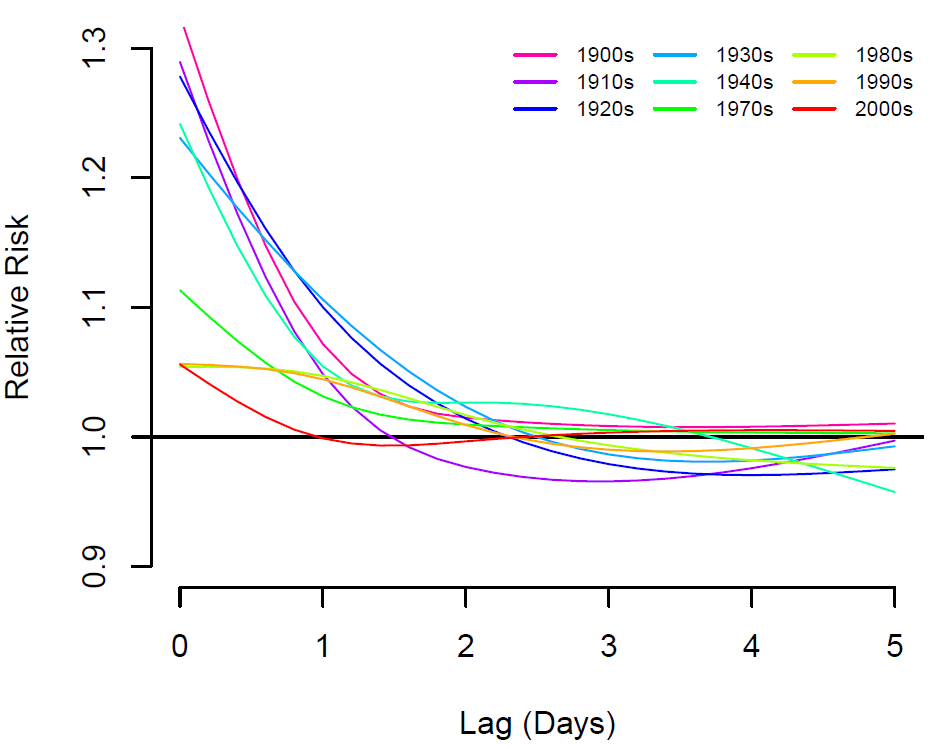
*eFigure 5* Lag-mortality curve associated with 29°C (corresponding to approximate the 99th percentile of annual temperature) relative to 22°C (corresponding to approximately the 80th percentile of annual temperature) on mortality in New York City by decade, 1900s-2000s for the 15-44 age group. Calculated using a distributed lag non-linear model with a quadratic spline with 4 degrees of freedom for the temperature and a natural cubic spline with 4 degrees of freedom for the lag.



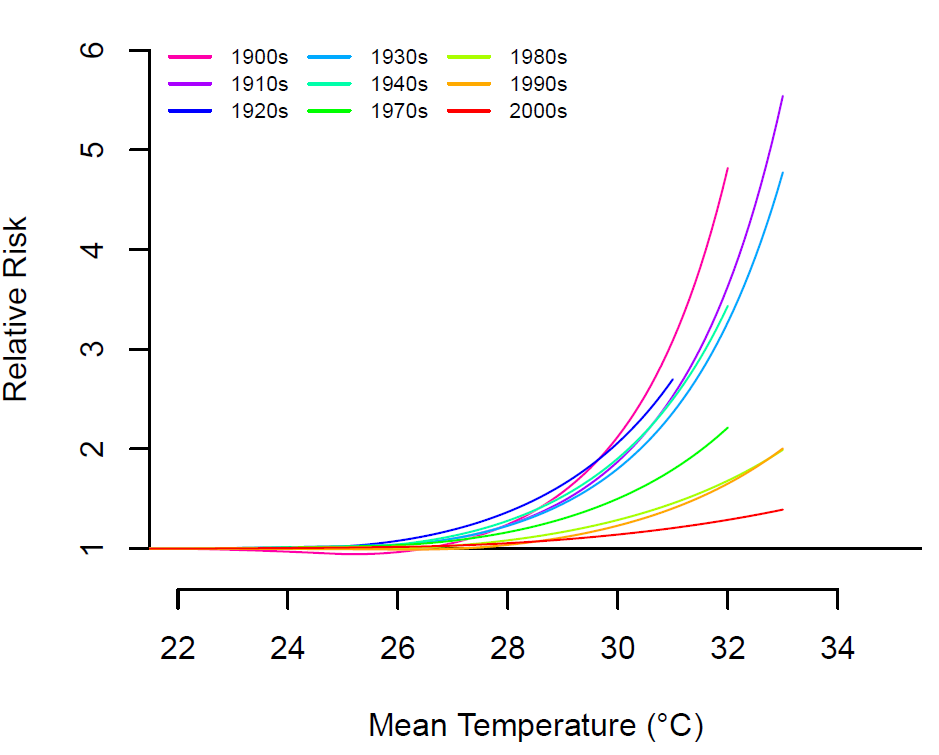
*eFigure 6* Temperature – mortality curves of overall cumulative risk for New York City by decade, 1900s -2000s, for the 45-64 age group. Calculated using a distributed lag non-linear model with a quadratic spline with 4 degrees of freedom for the temperature and a natural cubic spline with 4 degrees of freedom for the lag and 22°C (corresponding to approximately the 80th percentile of annual temperature) as a reference temperature.



*eFigure 7* Lag-mortality curve associated with 29°C (corresponding to approximate the 99th percentile of annual temperature) relative to 22°C (corresponding to approximately the 80th percentile of annual temperature) on mortality in New York City by decade, 1900s-2000s, for the 45-64 age group. Calculated using a distributed lag non-linear model with a quadratic spline with 4 degrees of freedom for the temperature and a natural cubic spline with 4 degrees of freedom for the lag.



*eFigure 8* Temperature – mortality curves of overall cumulative risk for New York City by decade, 1900s -2000s, for the over 65 age group. Calculated using a distributed lag non-linear model with a quadratic spline with 4 degrees of freedom for the temperature and a natural cubic spline with 4 degrees of freedom for the lag and 22°C (corresponding to approximately the 80th percentile of annual temperature) as a reference temperature.



*eFigure 9* Lag-mortality curve associated with 29°C (corresponding to approximate the 99th percentile of annual temperature) relative to 22°C (corresponding to approximately the 80th percentile of annual temperature) on mortality in New York City by decade, 1900s-2000s, for the over 65 age group. Calculated using a distributed lag non-linear model with a quadratic spline with 4 degrees of freedom for the temperature and a natural cubic spline with 4 degrees of freedom for the lag.



*eTable 1* Annual deaths a) reported in the Summary of Vital Statistics for NYC and b) calculated from daily mortality data used in this study.

|  |  |  |  |
| --- | --- | --- | --- |
| Year | Reported deaths a | Calculated deaths b | Difference, % of reported |
| 1898 | 66294 | 66473 | 0.27 |
| 1899 | 65343 | 65623 | 0.43 |
| 1900 | 70872 | 71356 | 0.68 |
| 1901 | 70980 | 70993 | 0.02 |
| 1902 | 68132 | 68361 | 0.34 |
| 1903 | 67864 | 68252 | 0.57 |
| 1904 | 78060 | 78388 | 0.42 |
| 1905 | 73714 | 74317 | 0.82 |
| 1906 | 76203 | 76746 | 0.71 |
| 1907 | 79205 | 79651 | 0.56 |
| 1908 | 73072 | 73575 | 0.69 |
| 1909 | 74375 | 74557 | 0.24 |
| 1910 | 76742 | 77714 | 1.27 |
| 1911 | 75423 | 75934 | 0.68 |
| 1912 | 73013 | 73311 | 0.41 |
| 1913 | 70902 | 74408 | 4.94 |
| 1914 | 74803 | 75755 | 1.27 |
| 1915 | 76193 | 78210 | 2.65 |
| 1916 | 78307 | 78873 | 0.72 |
| 1917 | 78575 | 78802 | 0.29 |
| 1918 | 98119 | 98904 | 0.80 |
| 1919 | 74433 | 75534 | 1.48 |
| 1920 | 73249 | 74831 | 2.16 |
| 1921 | 64257 | 65802 | 2.40 |
| 1922 | 69690 | 71466 | 2.55 |
| 1923 | 69452 | 71514 | 2.97 |
| 1924 | 71252 | 73250 | 2.80 |
| 1925 | 71914 | 73098 | 1.65 |
| 1926 | 76082 | 77157 | 1.41 |
| 1927 | 70430 | 71073 | 0.91 |
| 1928 | 78091 | 79387 | 1.66 |
| 1929 | 77482 | 79245 | 2.28 |
| 1930 | 74888 | 77077 | 2.92 |
| 1931 | 77418 | 78619 | 1.55 |
| 1932 | 74319 | 75345 | 1.38 |
| 1933 | 75153 | 76174 | 1.36 |
| 1934 | 75857 | 76927 | 1.41 |
| 1935 | 75057 | 76064 | 1.34 |
| 1936 | 77638 | 77996 | 0.46 |
| 1937 | 77465 | 77716 | 0.32 |
| 1938 | 73775 | 74033 | 0.35 |
| 1939 | 75439 | 75762 | 0.43 |
| 1940 | 76008 | 76576 | 0.75 |
| 1941 | 74553 | 75174 | 0.83 |
| 1942 | 75675 | 76363 | 0.91 |
| 1943 | 83174 | 83971 | 0.96 |
| 1944 | 78783 | 79528 | 0.95 |
| 1945 | 79726 | 80620 | 1.12 |
| 1946 | 78481 | 79477 | 1.27 |
| 1947 | 80733 | 82680 | 2.41 |
| 1948 | 81651 | 82864 | 1.49 |

*eTable 2* Sensitivity analysis on lag duration and number of degrees of freedom for the temperature and lag. Overall cumulative relative risk at 29˚C (corresponding to approximately the 99th percentile of annual temperature) relative to 22°C (corresponding to approximately the 80th percentile of annual temperature) on mortality in adults (age 15 or older) in New York City by decade, 1900s-2000s.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Model | lag | lag df | temp df | 1900 - 1909 | 1910 - 1919 | 1920 - 1929 | 1930 - 1939 | 1940 - 1948 | 1973 - 1979 | 1980 - 1989 | 1990 - 1999 | 2000 - 2006 |
| main | **5** | **4** | **4** | **1.43 (1.37,1.49)** | **1.30 (1.25,1.36)** | **1.39 (1.34,1.45)** | **1.36 (1.32,1.41)** | **1.39 (1.35,1.44)** | **1.26 (1.22,1.29)** | **1.15 (1.12,1.17)** | **1.11 (1.09,1.14)** | **1.09 (1.05,1.12)** |
| 2 | **5** | **3** | **4** | **1.43 (1.37,1.49)** | **1.30 (1.24,1.35)** | **1.39 (1.33,1.45)** | **1.36 (1.31,1.40)** | **1.39 (1.35,1,43)** | **1.26 (1.22,1.29)** | **1.15 (1.12,1.17)** | **1.11 (1.09,1.14)** | **1.08 (1.05,1.12)** |
| 3 | **5** | **3** | **5** | **1.25 (1.19,1.31)** | **1.24 (1.17,1.32)** | **1.35 (1.29,1.42)** | **1.29 (1.24,1.34)** | **1.33 (1.29,1.38)** | **1.24 (1.20,1.29)** | **1.14 (1.11,1.17)** | **1.07 (1.04,1.11)** | **1.09 (1.04,1.13)** |
| 4 | **5** | **3** | **6** | **1.16 (1.10,1.22)** | **1.29 (1.21,1.37)** | **1.32 (1.25,1.38)** | **1.24 (1.18, 1.30)** | **1.29 (1.24, 1.34)** | **1.25 (1.20, 1.31)** | **1.13 (1.10, 1.16)** | **1.09 (1.05, 1.12)** | **1.09 (1.04,1.13)** |
| 5 | **5** | **4** | **5** | **1.26 (1.20,1.32)** | **1.25 (1.18,1.32)** | **1.36 (1.30, 1.42)** | **1.30 (1.25, 1.35)** | **1.34 (1.29, 1.39)** | **1.24 (1.20, 1.29)** | **1.14 (1.11, 1.17)** | **1.08 (1.04, 1.11)** | **1.09 (1.04, 1.13)** |
| 6 | **5** | **4** | **6** | **1.16 (1.11, 1.22)** | **1.30 (1.23, 1.38)** | **1.32 (1.26, 1.39)** | **1.25 (1.19, 1.31)** | **1.30 (1.24, 1.35)** | **1.26 (1.21, 1.31)** | **1.13 (1.10, 1.17)** | **1.09 (1.06, 1.12)** | **1.09 (1.04, 1.13)** |
| 7 | **5** | **5** | **4** | **1.42 (1.36, 1.48)** | **1.30 (1.25, 1.36)** | **1.39 (1.33, 1.45)** | **1.36 (1.32, 1.41)** | **1.39 (1.34, 1.43)** | **1.25 (1.22, 1.29)** | **1.15 (1.12, 1.17)** | **1.11 (1.08, 1.14)** | **1.08 (1.05, 1.12)** |
| 8 | **5** | **5** | **5** | **1.25 (1.20, 1.31)** | **1.25 (1.18, 1.33)** | **1.36 (1.30, 1.42)** | **1.29 (1.24, 1.34)** | **1.34 (1.29, 1.38)** | **1.24 (1.20, 1.28)** | **1.14 (1.11, 1.17)** | **1.07 (1.04, 1.11)** | **1.08 (1.04, 1.13)** |
| 9 | **5** | **5** | **6** | **1.16 (1.11, 1.22)** | **1.30 (1.23, 1.38)** | **1.32 (1.25, 1.38)** | **1.25 (1.19, 1.31)** | **1.29 (1.24, 1.34)** | **1.25 (1.20, 1.30)** | **1.13 (1.10, 1.17)** | **1.09 (1.05, 1.12)** | **1.09 (1.04, 1.13)** |
| 10 | **10** | **3** | **4** | **1.35 (1.28, 1.43)** | **1.28 (1.20, 1.36)** | **1.20 (1.12, 1.28)** | **1.28 (1.22, 1.35)** | **1.29 (1.24, 1.35)** | **1.25 (1.20, 1.31)** | **1.15 (1.11, 1.18)** | **1.12 (1.08, 1.16)** | **1.11 (1.06, 1.15)** |
| 11 | **10** | **3** | **5** | **1.16 (1.09, 1.24)** | **1.24 (1.14, 1.36)** | **1.19 (1.12, 1.28)** | **1.22 (1.16, 1.29)** | **1.23 (1.17, 1.29)** | **1.23 (1.17, 1.29)** | **1.13 (1.09, 1.17)** | **1.08 (1.04, 1.12)** | **1.10 (1.04, 1.16)** |
| 12 | **10** | **3** | **6** | **1.10 (1.02, 1.18)** | **1.33 (1.22, 1.46)** | **1.19 (1.11, 1.28)** | **1.17 (1.10, 1.25)** | **1.19 (1.13, 1.26)** | **1.23 (1.17, 1.30)** | **1.12 (1.08, 1.17)** | **1.10 (1.06, 1.14)** | **1.10 (1.05, 1.16)** |
| 13 | **10** | **4** | **4** | **1.36 (1.29, 1.44)** | **1.29 (1.22, 1.36)** | **1.22 (1.15, 1.30)** | **1.30 (1.24, 1.36)** | **1.30 (1.25, 1.36)** | **1.26 (1.21, 1.31)** | **1.15 (1.12, 1.18)** | **1.13 (1.09, 1.16)** | **1.11 (1.07, 1.16)** |
| 14 | **10** | **4** | **5** | **1.17 (1.10, 1.25)** | **1.26 (1.16, 1.37)** | **1.22 (1.14, 1.30)** | **1.24 (1.18, 1.30)** | **1.25 (1.19, 1.31)** | **1.23 (1.17, 1.29)** | **1.13 (1.09, 1.17)** | **1.09 (1.05, 1.13)** | **1.11 (1.05, 1.16)** |
| 15 | **10** | **4** | **6** | **1.10 (1.03, 1.18)** | **1.36 (1.25, 1.48)** | **1.22 (1.14, 1.31)** | **1.19 (1.12, 1.26)** | **1.21 (1.15, 1.28)** | **1.24 (1.17, 1.31)** | **1.13 (1.08, 1.17)** | **1.10 (1.06, 1.14)** | **1.11 (1.05, 1.16)** |
| 16 | **10** | **5** | **4** | **1.36 (1.29, 1.44)** | **1.28 (1.21, 1.35)** | **1.22 (1.15, 1.30)** | **1.29 (1.23, 1.35)** | **1.31 (1.25, 1.36)** | **1.25 (1.21, 1.31)** | **1.15 (1.11, 1.18)** | **1.12 (1.09, 1.16)** | **1.11 (1.07, 1.16)** |
| 17 | **10** | **5** | **5** | **1.17 (1.10, 1.24)** | **1.27 (1.17, 1.37)** | **1.21 (1.14, 1.29)** | **1.23 (1.17, 1.29)** | **1.25 (1.19, 1.31)** | **1.23 (1.17, 1.29)** | **1.13 (1.09, 1.17)** | **1.09 (1.05, 1.13)** | **1.11 (1.05, 1.16)** |
| 18 | **10** | **5** | **6** | **1.11 (1.03, 1.18)** | **1.36 (1.25, 1.48)** | **1.22 (1.14, 1.30)** | **1.18 (1.11, 1.25)** | **1.22 (1.16, 1.28)** | **1.24 (1.17, 1.31)** | **1.13 (1.09, 1.17)** | **1.10 (1.06, 1.14)** | **1.11 (1.05, 1.16)** |

*eTable 3* Akaike’s Information Criterion for quasi-Poisson (Q-AIC) for models presented in *Table S 2*

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Model | lag | lag df | temp df | 1900 - 1909 | 1910 - 1919 | 1920 - 1929 | 1930 - 1939 | 1940 - 1948 | 1973 - 1979 | 1980 - 1989 | 1990 - 1999 | 2000 - 2006 |
| main | **5** | **4** | **4** | **9962** | **9764** | **9523** | **9749** | **9221** | **7054** | **9705** | **9551** | **6505** |
| 2 | **5** | **3** | **4** | **9993** | **9832** | **9555** | **9784** | **9244** | **7053** | **9704** | **9554** | **6512** |
| 3 | **5** | **3** | **5** | **9716** | **9833** | **9534** | **9746** | **9201** | **7066** | **9706** | **9539** | **6510** |
| 4 | **5** | **3** | **6** | **9563** | **9852** | **9528** | **9735** | **9174** | **7065** | **9717** | **9550** | **6508** |
| 5 | **5** | **4** | **5** | **9690** | **9766** | **9500** | **9708** | **9187** | **7072** | **9708** | **9538** | **6506** |
| 6 | **5** | **4** | **6** | **9539** | **9786** | **9492** | **9689** | **9155** | **7074** | **9716** | **9551** | **6509** |
| 7 | **5** | **5** | **4** | **9931** | **9774** | **9533** | **9751** | **9213** | **7060** | **9713** | **9555** | **6503** |
| 8 | **5** | **5** | **5** | **9668** | **9779** | **9507** | **9703** | **9178** | **7080** | **9718** | **9545** | **6506** |
| 9 | **5** | **5** | **6** | **9529** | **9799** | **9502** | **9674** | **9150** | **7083** | **9727** | **9560** | **6511** |
| 10 | **10** | **3** | **4** | **9784** | **9639** | **9111** | **9471** | **8902** | **6771** | **9300** | **9180** | **6217** |
| 11 | **10** | **3** | **5** | **9489** | **9633** | **9105** | **9458** | **8859** | **6781** | **9303** | **9161** | **6219** |
| 12 | **10** | **3** | **6** | **9338** | **9652** | **9106** | **9451** | **8846** | **6784** | **9315** | **9163** | **6219** |
| 13 | **10** | **4** | **4** | **9566** | **9353** | **8925** | **9305** | **8727** | **6740** | **9280** | **9147** | **6209** |
| 14 | **10** | **4** | **5** | **9280** | **9341** | **8926** | **9272** | **8688** | **6754** | **9287** | **9129** | **6213** |
| 15 | **10** | **4** | **6** | **9140** | **9350** | **8925** | **9264** | **8672** | **6754** | **9301** | **9133** | **6212** |
| 16 | **10** | **5** | **4** | **9552** | **9320** | **8918** | **9273** | **8735** | **6745** | **9282** | **9147** | **6207** |
| 17 | **10** | **5** | **5** | **9269** | **9312** | **8921** | **9241** | **8699** | **6762** | **9289** | **9129** | **6214** |
| 18 | **10** | **5** | **6** | **9126** | **9325** | **8922** | **9235** | **8681** | **6765** | **9299** | **9136** | **6218** |