Seasonal Patterns of Age at Death

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The child first and always

Seasonal effects on disease

Changes in the seasons are particularly productive of diseases, as are times of great changes in cold and heat

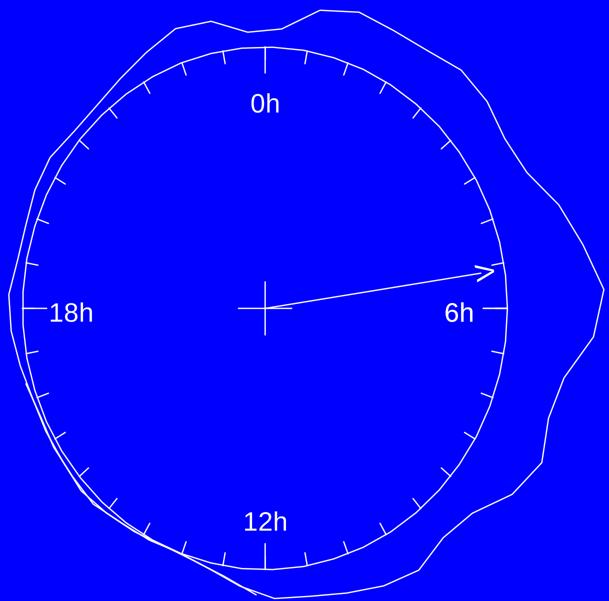
Hippocrates

Seasonal variation at presentation

- Mostly due to environmental factors
  - Climatic: temperature, rainfall, atmospheric pressure, hours of sun…
  - Social: holidays, social class
  - Location: latitude (shifts Northern/Southern hemispheres)

Seasonal variation at presentation

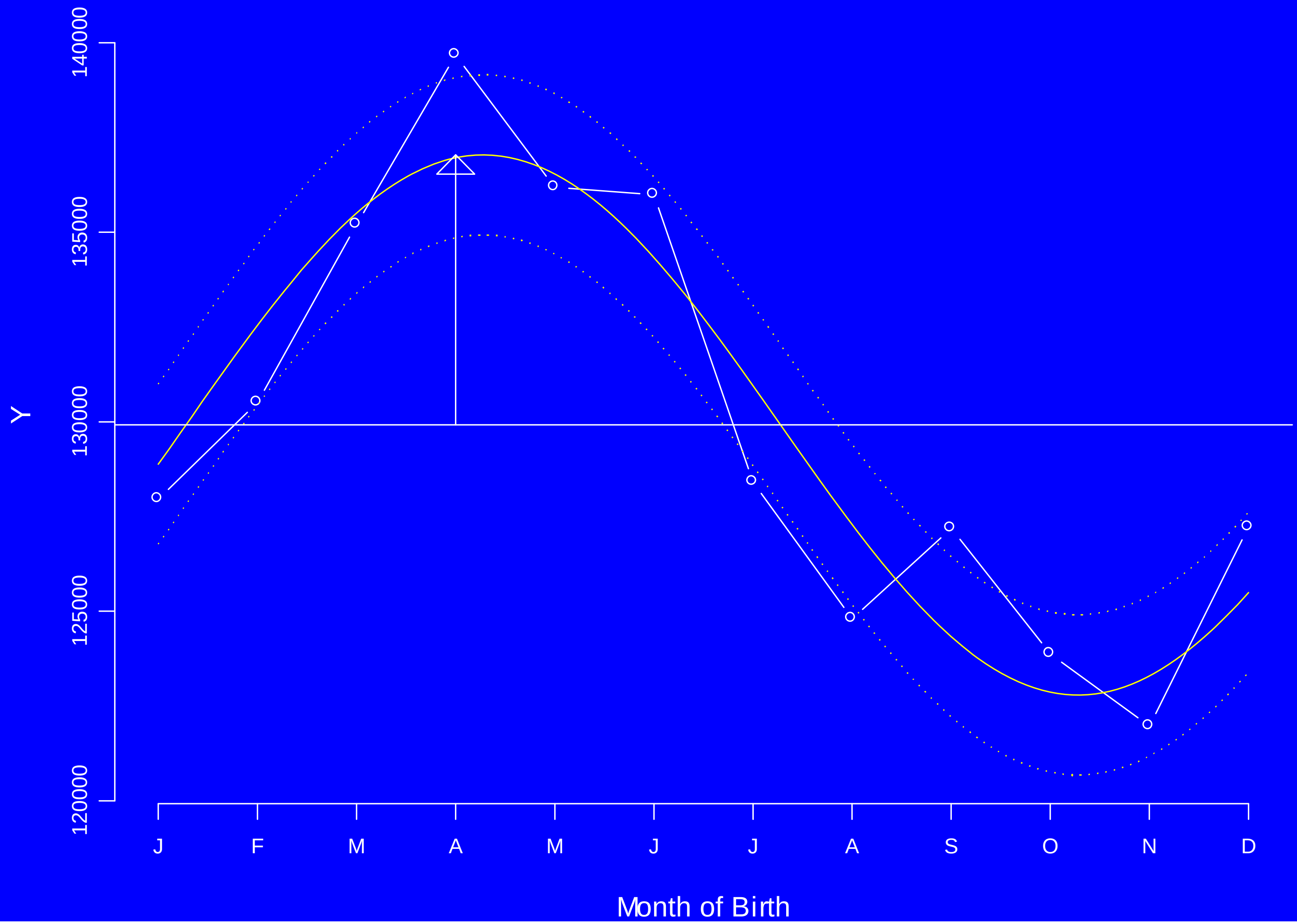
- Birth
  - Hour of birth: most births occur before noon



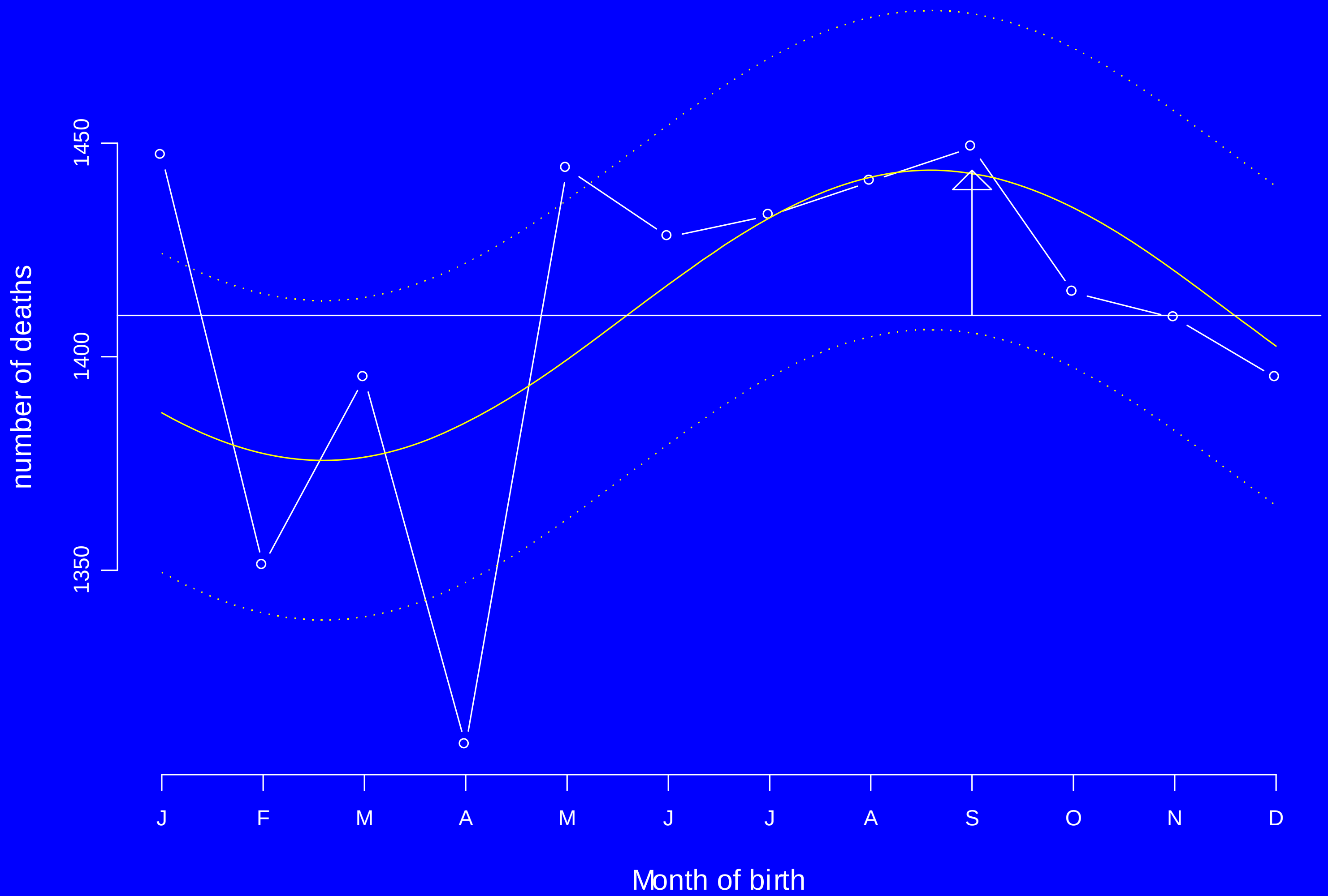
Hour of birth in Valle del Mezquital 1969-1971, *n* = 4863

Source: D'Aloja, Anales de Antrop (1983)

Month of birth of those who died >50 in Scotland, 1974-2001, *n* = 1,581,492



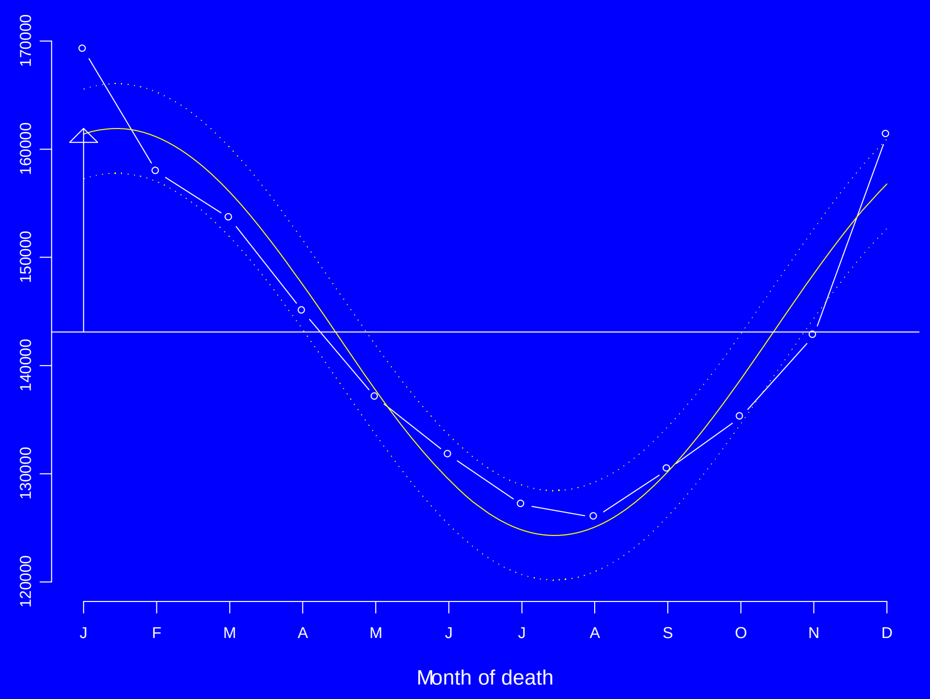
Month of birth of those who died <1 in Scotland, 1974-2001, *n* = 17,168



Seasonal variation at presentation

- Death
  - More elderly deaths occur in Winter
  - More homicides occur in Summer
  - More suicides occur in Spring and Summer
  - Sudden Infant Death Syndrome (Summer)

Scotland: all deaths 1974-2001



Seasonal variation at presentation: suicides in Scotland

Seasonal variation at presentation

- Cancer: leukemia, skin cancer (Summer)
- Aortal aneurisms (high atmospheric pressure)
- Retinal detachment (Summer)
- Child's type I diabetes mellitus (Winter)

Seasonal variation in date of birth

- Events occuring between conception and birth, and very shortly afterwards do have a lasting effect in adult health
- Dates of birth/conception may refer to environmental factors affecting maternal and child's health
- Reasons still largely unknown

Seasonal variation in date of birth

- Barker et al.'s (controversial) Programming theory tries to explain the role of environmental factors in fetal origins of adult disease
- Criticism: is the strong correlation between early environment and adult mortality:
  - an effect of continued deprivation over the whole life course OR
  - an indication of factors that act early in life/prenatally?

Seasonal variation in date of birth

- Examples:
  - Mental illnesses: Schizophrenia (Winter; in the tropics linked to rainfall), Anorexia nervosa (Winter), Suicide (Spring)
  - Chronic diseases: diabetes (Spring)
  - Cleft Lips and Palate (Summer)
  - Sudden Infant Death Syndrome (Spring)
  - Diabetes Mellitus (Spring)
  - Adult height (6mm taller in Spring)
  - Lifespan (larger life expectation in Autumn)

Longevity and date of birth

- Some recent studies have shown that expected lifespan depends on month of birth:
  - Moore et al. (1997, 1998)
    - Data from rural Gambia: seasonality linked to amount of resources available in the first months of life
  - Vaiserman et al. (2002)
    - Data from Kiev, 1988-2000
    - Shows a larger lifespan for those born in Autumn
  - Doblhammer & Vaupel (2001)
    - Data from Denmark (1968-2000) & Austria (1988-1996)
    - Shift in Australian-born Australians vs Northern hemisphere immigrants (1993-1997)
  - Doblhammer (20??)
    - Data from USA 1989-1997
    - Seasonal trends in lifespan in some causes of death and ethnic groups

Doblhammer & Vaupel's results

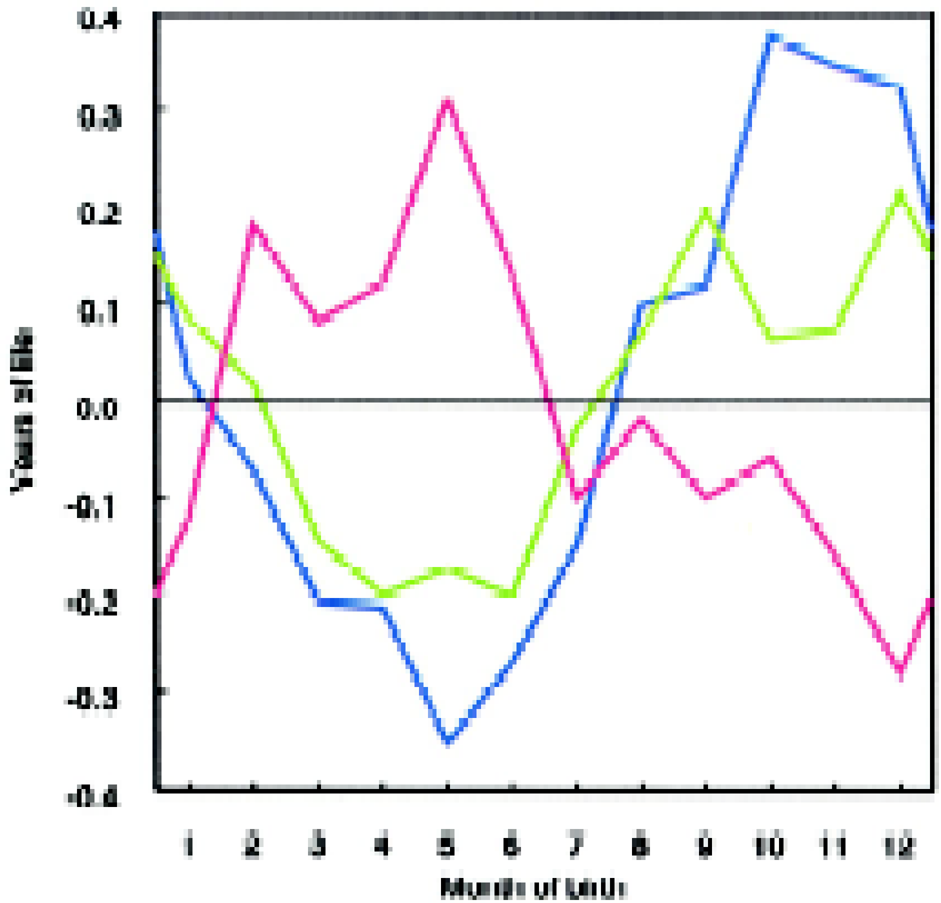


Fig. 1. Deviation in remaining lifespan of people born in specific months from the average remaining lifespan at age 50. In the Northern Hemisphere countries of Denmark (green line) and Austria (blue line), the people born in the fourth quarter of the year live longer than those born in the second quarter. For Australia (red line), the pattern is shifted by half a year.

Aims

- Analyse influence of date of birth on
  - Age at death after age 50
  - Extreme longevity
- Adjusting by
  - Gender
  - Cause of death
  - Marital Status
- Using
  - All deaths recorded in Scotland between 1974 and 2001

Data

The data comprise all deaths recorded in Scotland between 1/1/1974 and 31/12/2001 (1,741,728 persons)

- Why investigate Scotland?
  - Further latitude than in previous studies (Austria, Denmark, USA, Ukraine)
  - General Register Office for Scotland: reliable vital statistics on birth and death dates available for a longer period of time than in previous studies

Data

- For each person we have
  - the exact dates of birth and death
  - cause of death (ICD 8,9,10 classifications)
  - gender
  - country of birth
  - marital status at death
  - the place where death occurred

Data

- We only included people born in the UK, Isle of Man, Channel Islands and Republic of Ireland who died in Scotland with known cause of death
- We excluded those whose registered age at death differed in more than one year with the age at death calculated from the birth and death dates
- For longevity analyses we only considered people aged 50 or more
- Total = 1’581,492 deaths

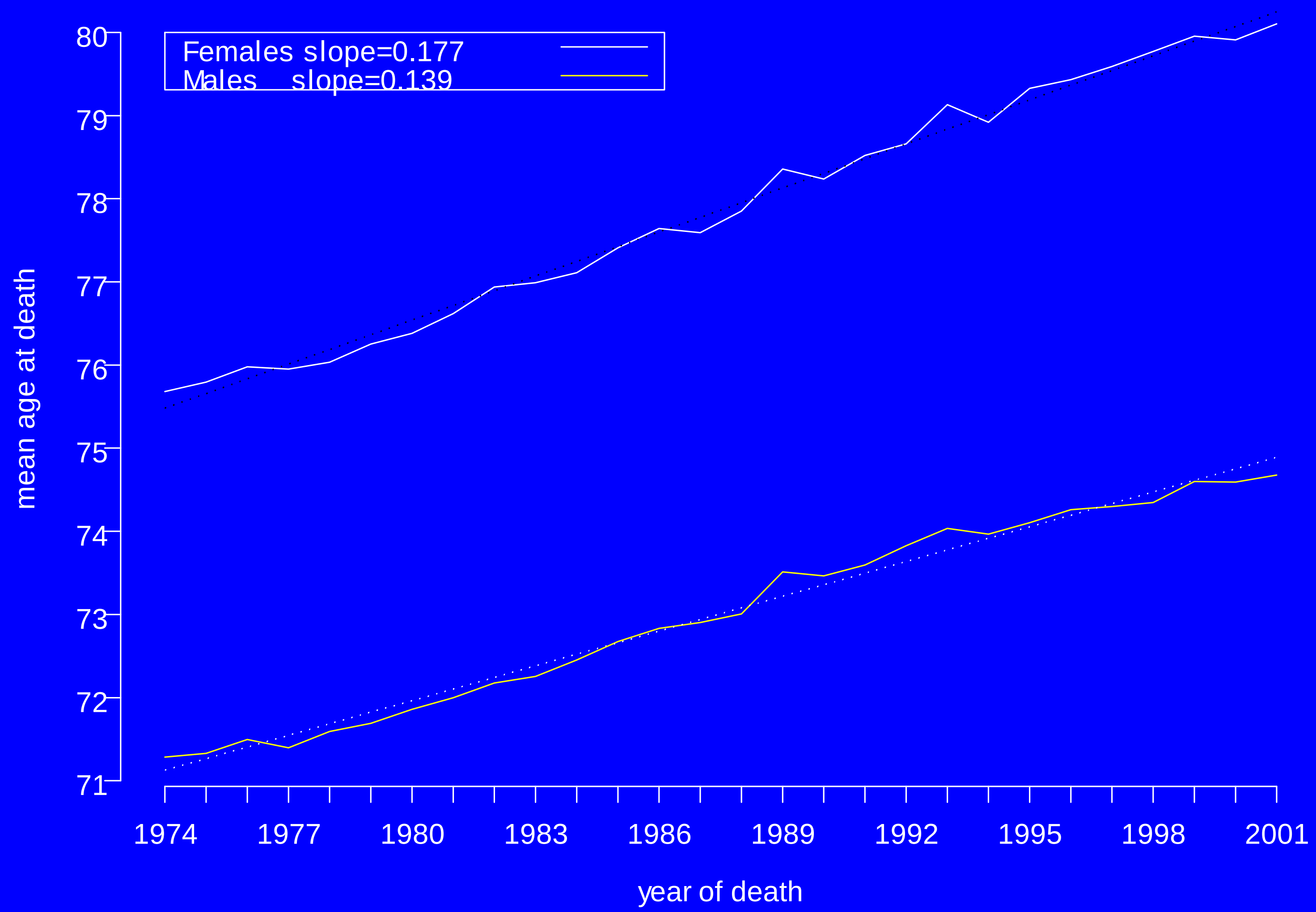
Causes of death

- ICD = International Cause of Death classification
- Versions 7,8,9,10 – over 6000 different causes
- Used five broad causes:
  - Circulatory & ischaemic heart disease
  - Infectious disease
  - Malignant neoplasms
  - Other diseases
  - External causes

Data

Sex	N	%	mean age
Female	830364	52.51	77.86
Male	751128	47.49	72.96
Marital status	N	%	mean age
Never married	221310	13.99	76.56
Married	641777	40.58	70.43
Widowed	671471	42.46	80.62
Divorced	44655	2.82	67.33
Not known	2279	0.14	73.37
Cause of death	N	%	mean age
Infectious disease	7686	0.49	74.50
Malignant neoplasms	372183	23.53	71.88
Circulatory diseases	797208	50.41	76.36
Other natural causes	362242	22.91	77.67
Accidents and suicides	42173	2.67	73.89
Total	1581492	100	75.53

Average age at death by year of death



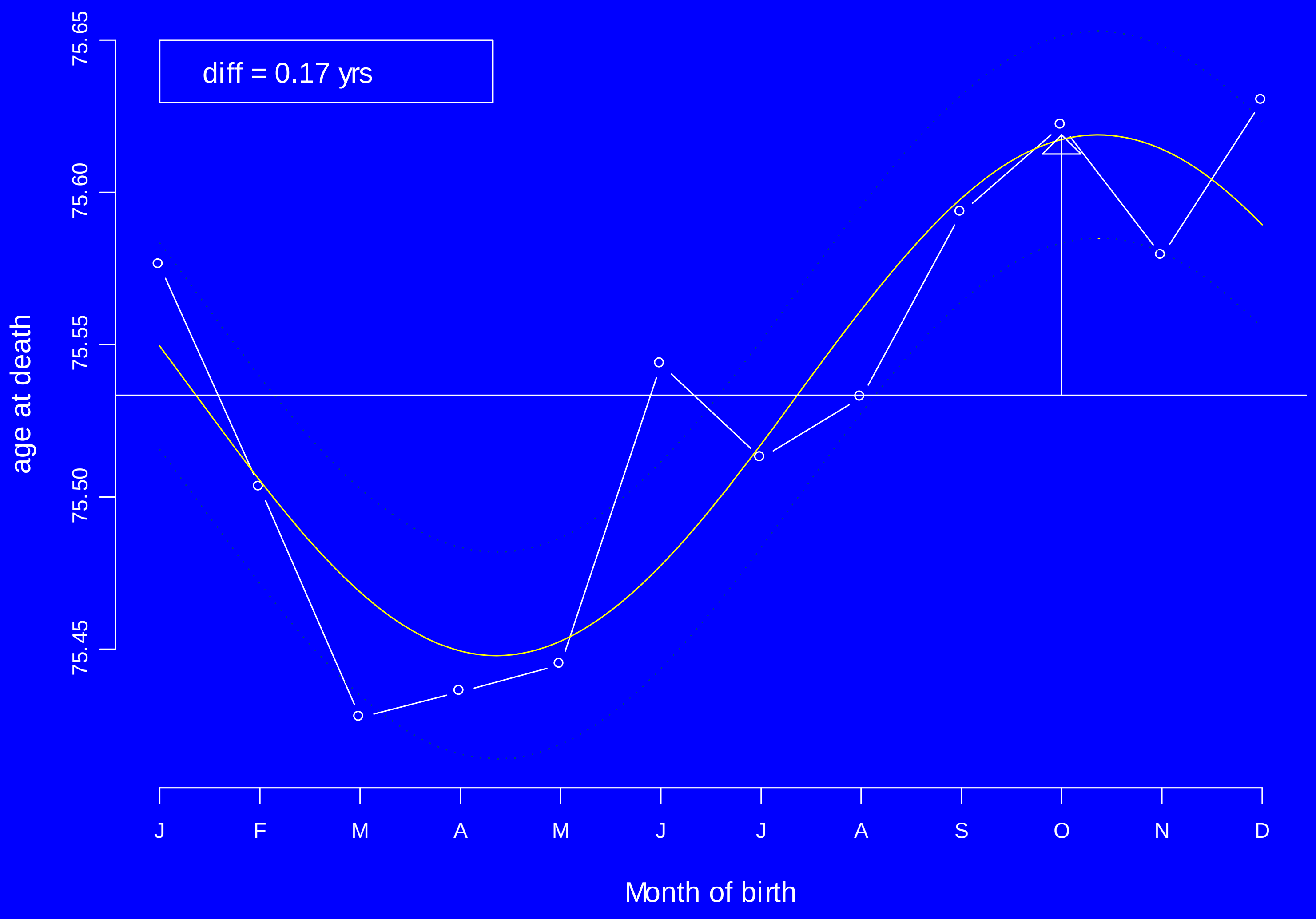
Data
Mean age at death by Sex:ICD:Marital status

	Married						Widowed				
	Infect	**neopl**	**circ**	**other**	**ext**		**infect**	**neopl**	**circ**	**other**	**ext**
Fem	68.2	66.3	71.2	70.2	67.0	Fem	80.6	77.3	81.8	82.7	82.0
Male	70.9	69.5	71.1	73.2	66.6	Male	78.6	77.2	79.2	80.8	77.5
	Never married						**Divorced**				
	infect	**neopl**	**circ**	**other**	**ext**		**infect**	**neopl**	**circ**	**other**	**ext**
Fem	77.7	75.1	80.9	81.4	80.0	Fem	66.9	66.4	72.0	70.5	65.9
Male	69.2	69.9	71.7	72.5	66.6	Male	65.4	65.6	66.2	65.5	60.7

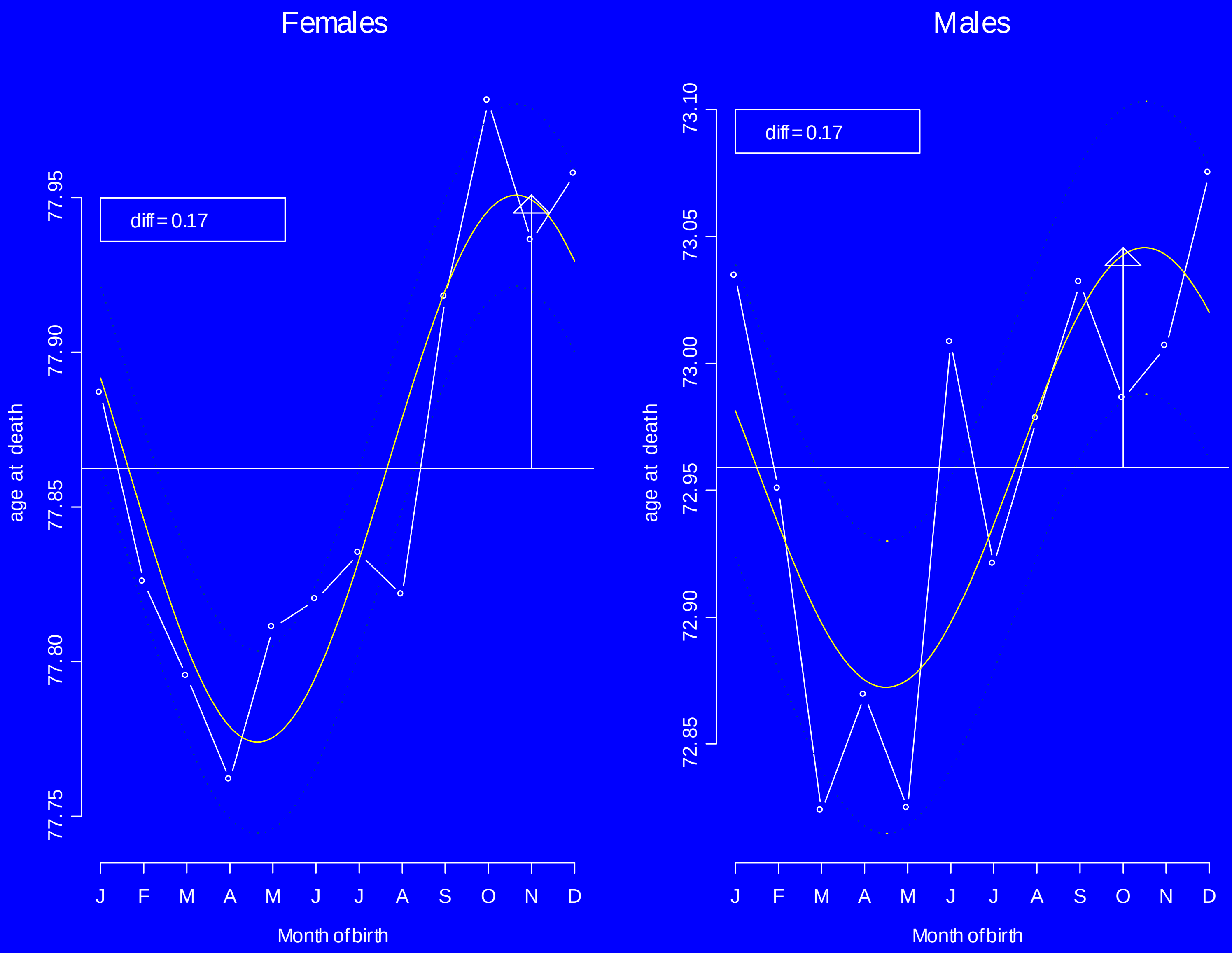
Data

- For each combination year of death/month of birth we calculated summary statistics (mean, quartiles, 95^{th} and 99^{th} quantile, maximum) of age at death
- We also obtained these summaries by gender*grouped cause of death*marital status

Scotland: mean age at death



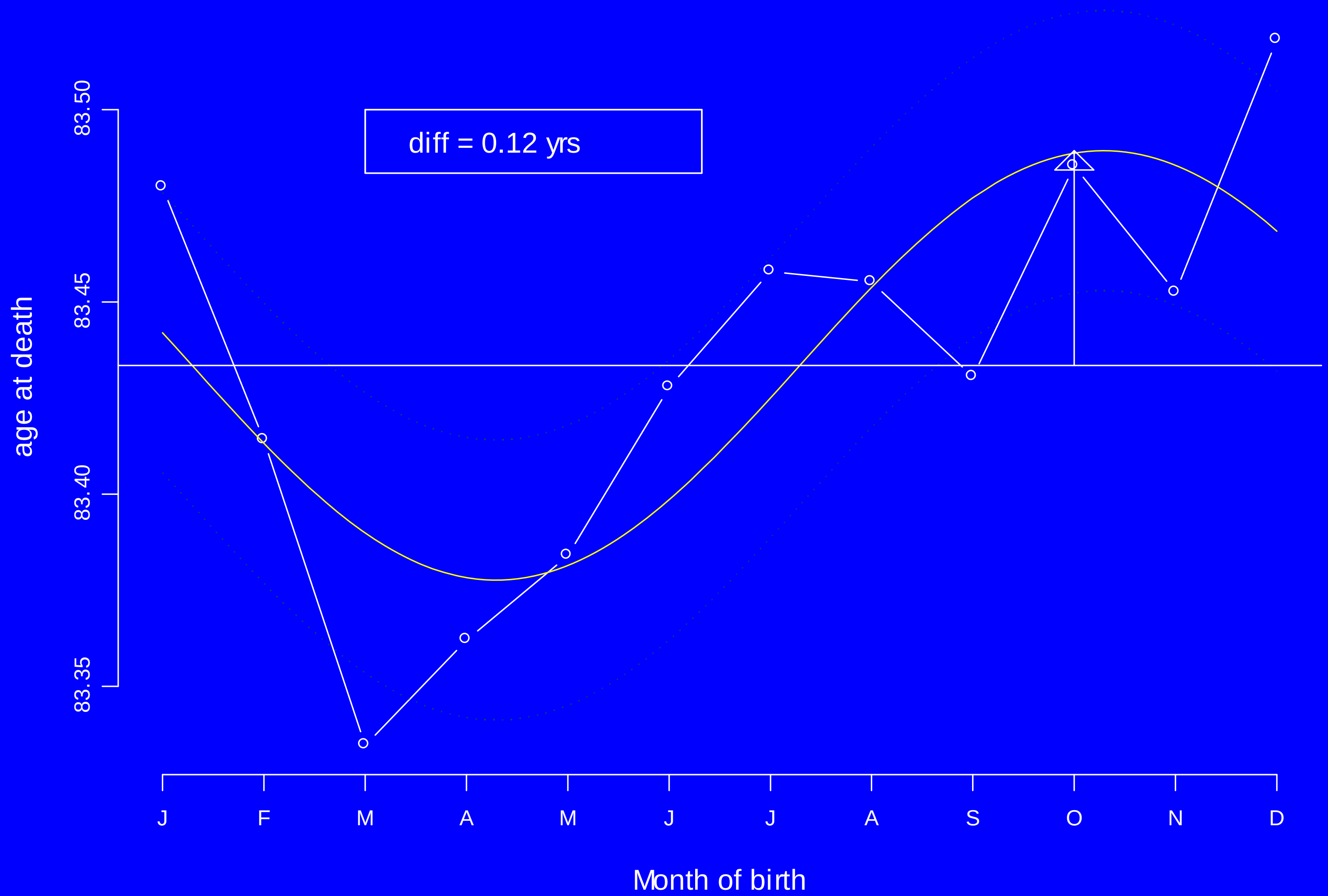
Scotland: mean age at death



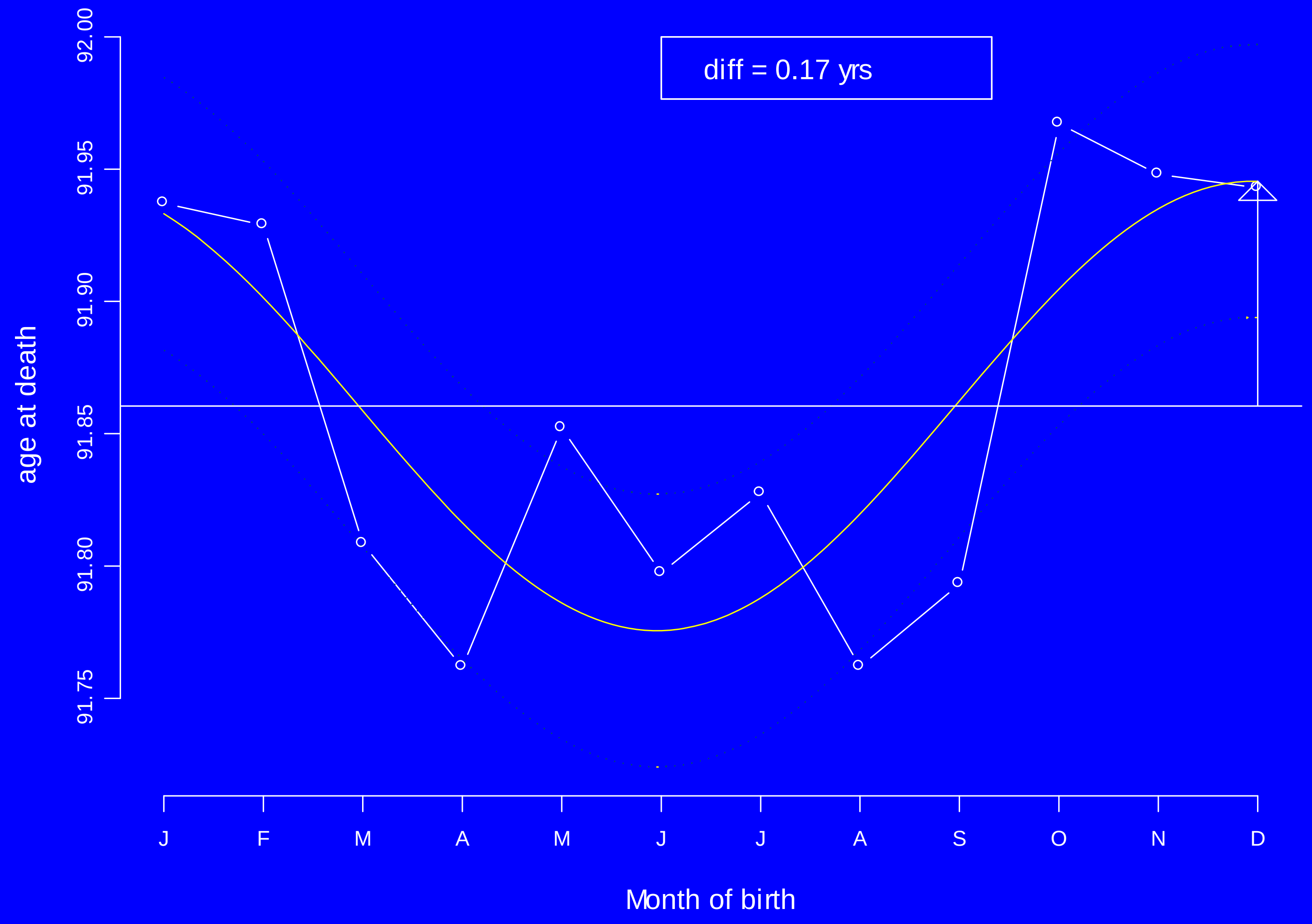
Comparisons for mean age at death

- Austria (deaths over 50 between 1988 and 1996)
  0.3 years
- Denmark (deaths over 50 between 1968 and 1998)
  0.6 years
- Australia (deaths over 50 between 1993 and 1997)
  0.35 years
- USA (all deaths between 1989 and 1997)
  0.44 years
- Ukraine (all deaths between 1988 and 2000)
  2.6 years!!

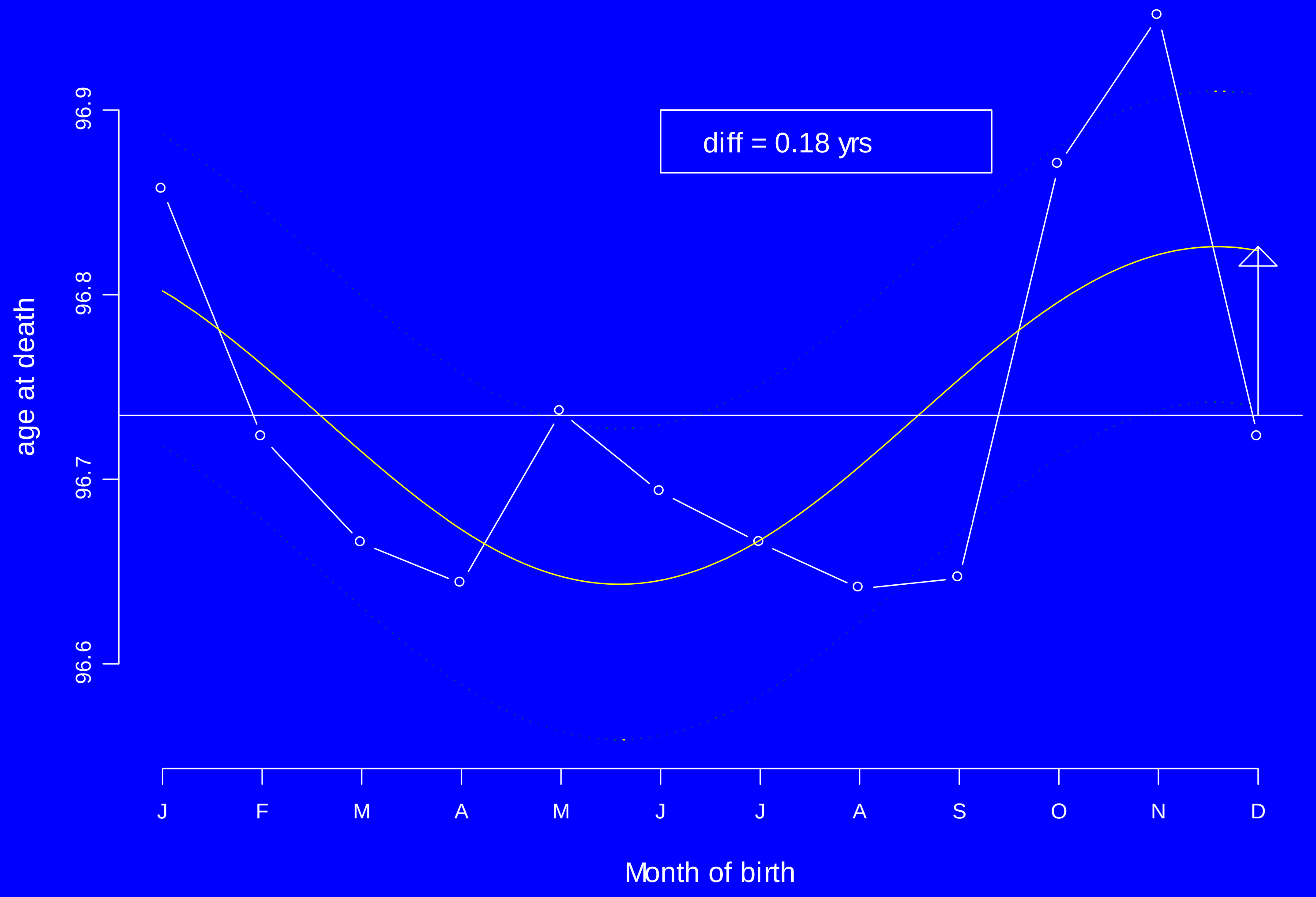
Scotland: Q3 of age at death



Scotland: q95 of age at death (about 6800 deaths at each month of birth)



Scotland: q99 of age at death (about 1400 deaths at each month of birth)



Poisson model for #(centenarians)

Let $c_t = \alpha + \beta t,$ where c_t is the numer of centenarians in month t. $t = 1, 2, ..., 336,$ be the trend;

(interaction seasonal:trend wasn't significant)

This gives the expected #(centenarians) assuming no seasonal variation is present

A GLM with Poisson error and log link is:

$$\ln(c_t) = \gamma \cos(\omega t) + \delta \sin(\omega t), \text{ where } \omega = \frac{2\pi}{12}$$

and was fitted using the linear trend values as an offset

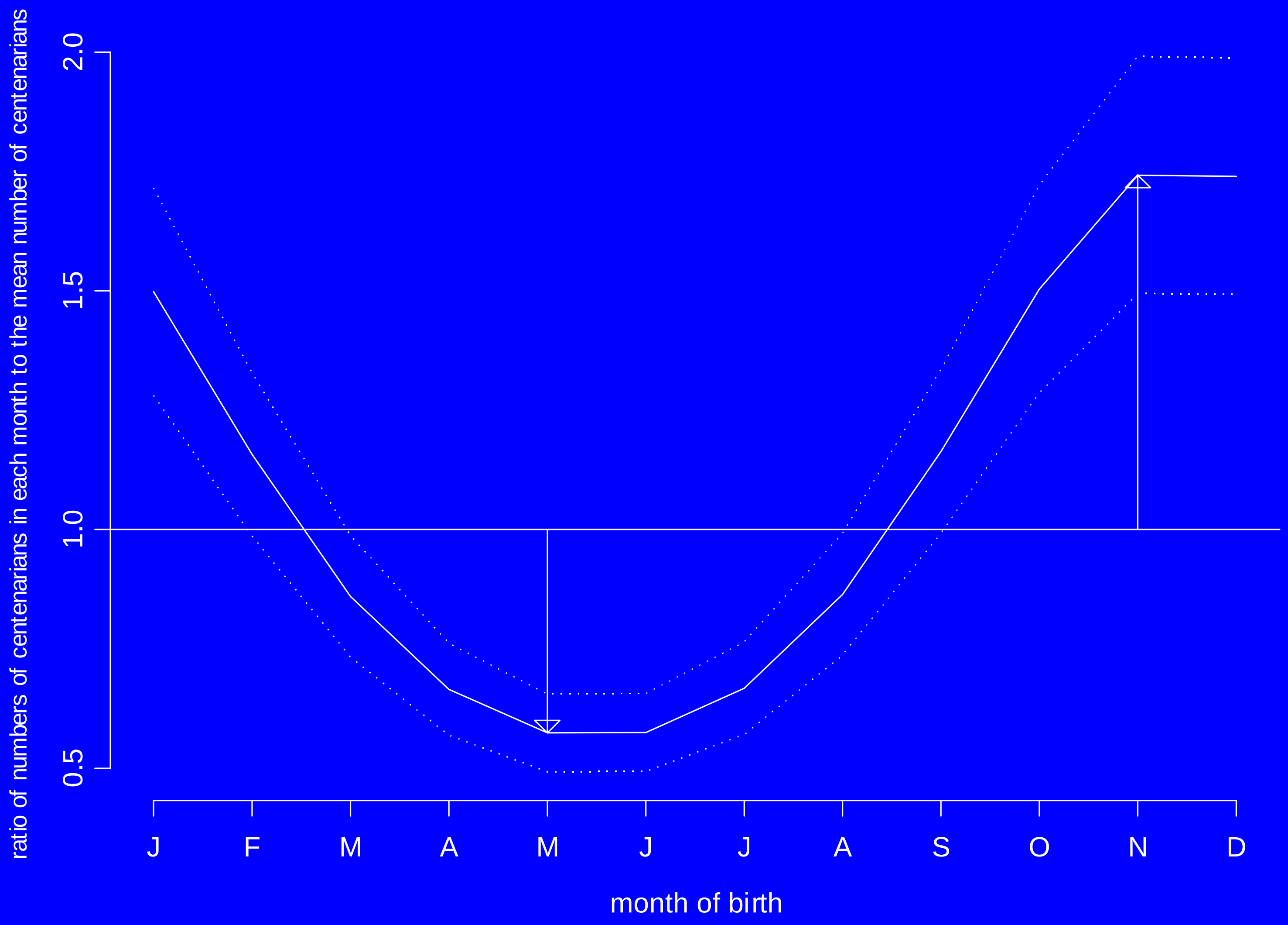
Poisson model for #(centenarians)

- This allows to compute the amplitude as

$$\nu = \sqrt{\gamma^2 + \delta^2}$$

which is the amplitude of the seasonal component as a ratio of the mean number of monthly deaths of centenarians.

Ratio of #(cents) by M of B to the mean #(cents)

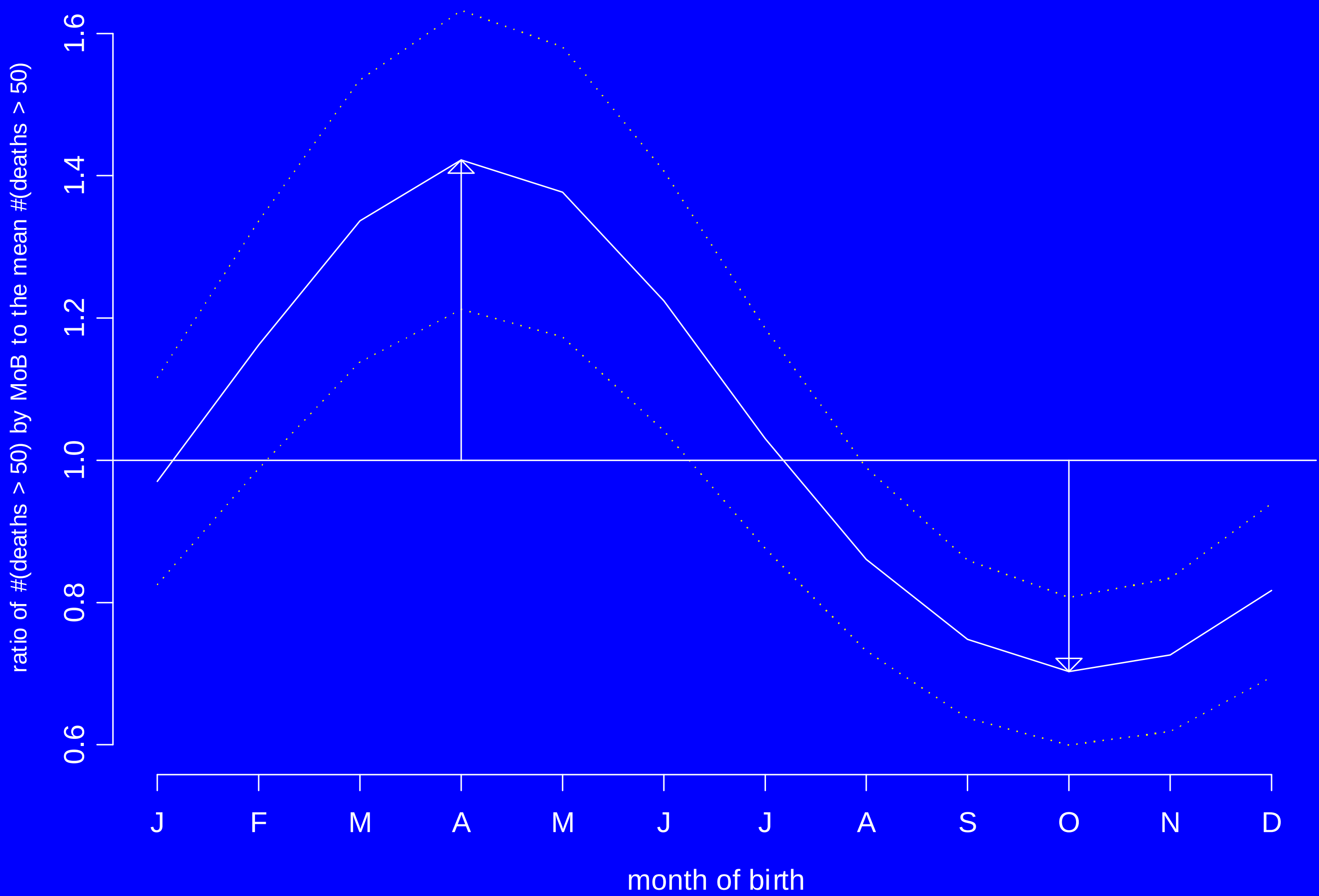


Survivorship of people born in the Southern Hemisphere

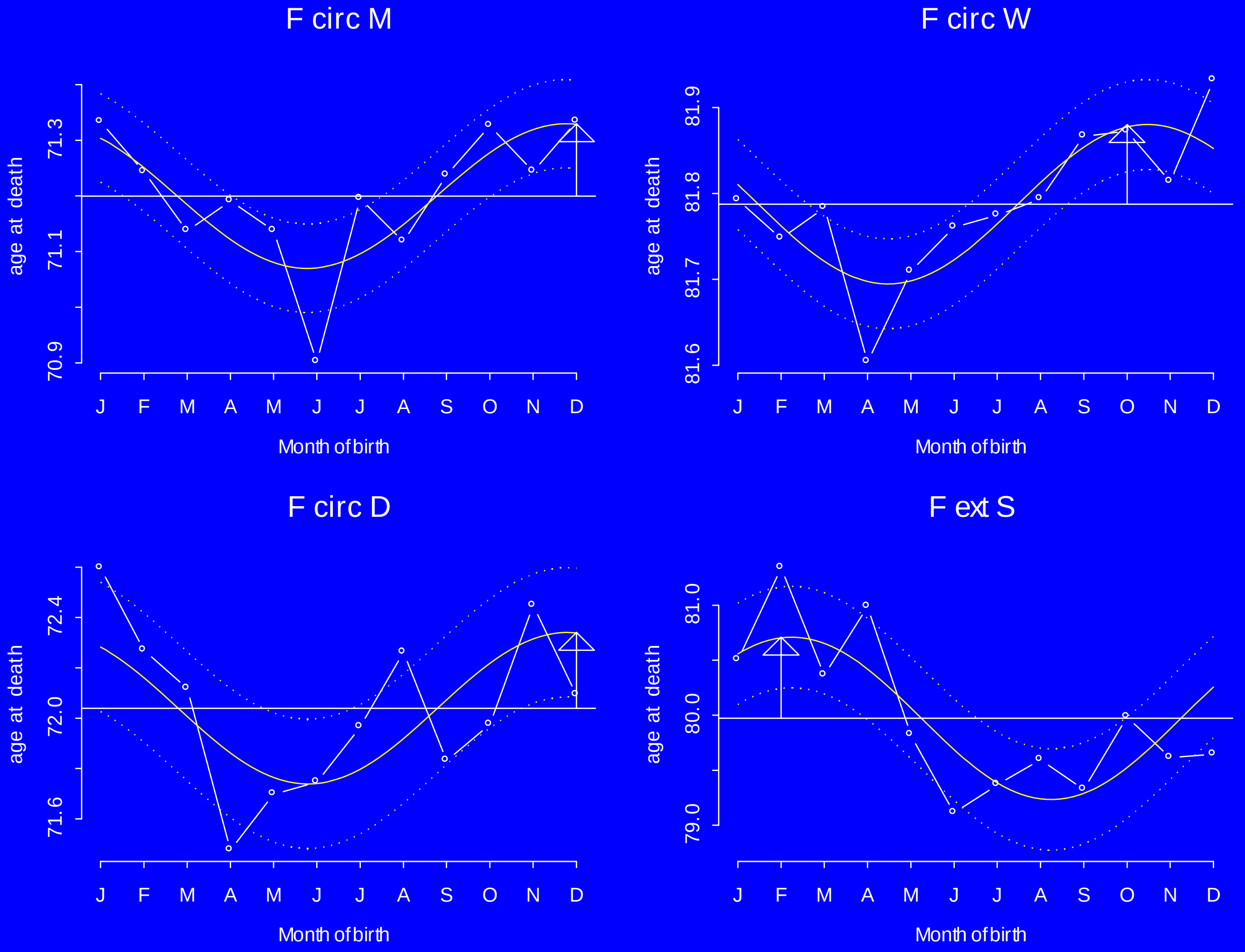
- Consider CofB = {Argentina, Australia, Chile, Falkland Is, Madagascar, New Zealand, Paraguay, Peru, South Africa, Zambia, Zimbabwe} who died aged >50 in Scotland 1974-2001
- Use the same Poisson model for #(deaths>50) by month of birth (n = 2848)

Ratio of #(deaths>50) by M of B to the mean #(deaths>50)

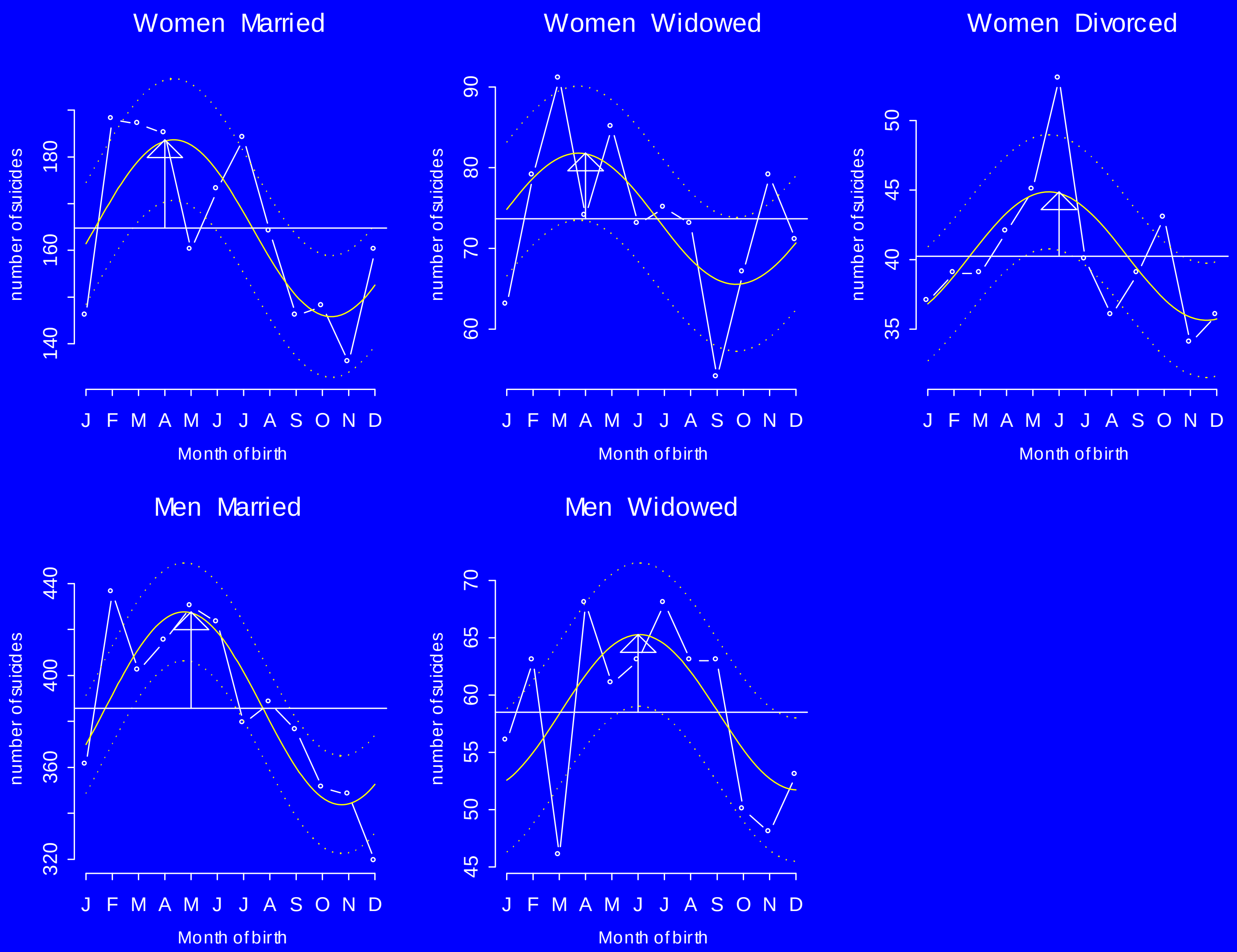
Southern Hemisphere countries



Mean Age at death by marital status and ICD



An application to suicide data



Increase of maximum lifespan

- Current (proven) record Jeanne Calment (died aged 122.45 years in France, 1997)
- Maximum age at death has increased steadily in the last 100 years
- Is this trend still growing?
  - Yes: improvement in public health amongst the elderly?
  - No: are we approaching a biological limit?

Increase of maximum lifespan

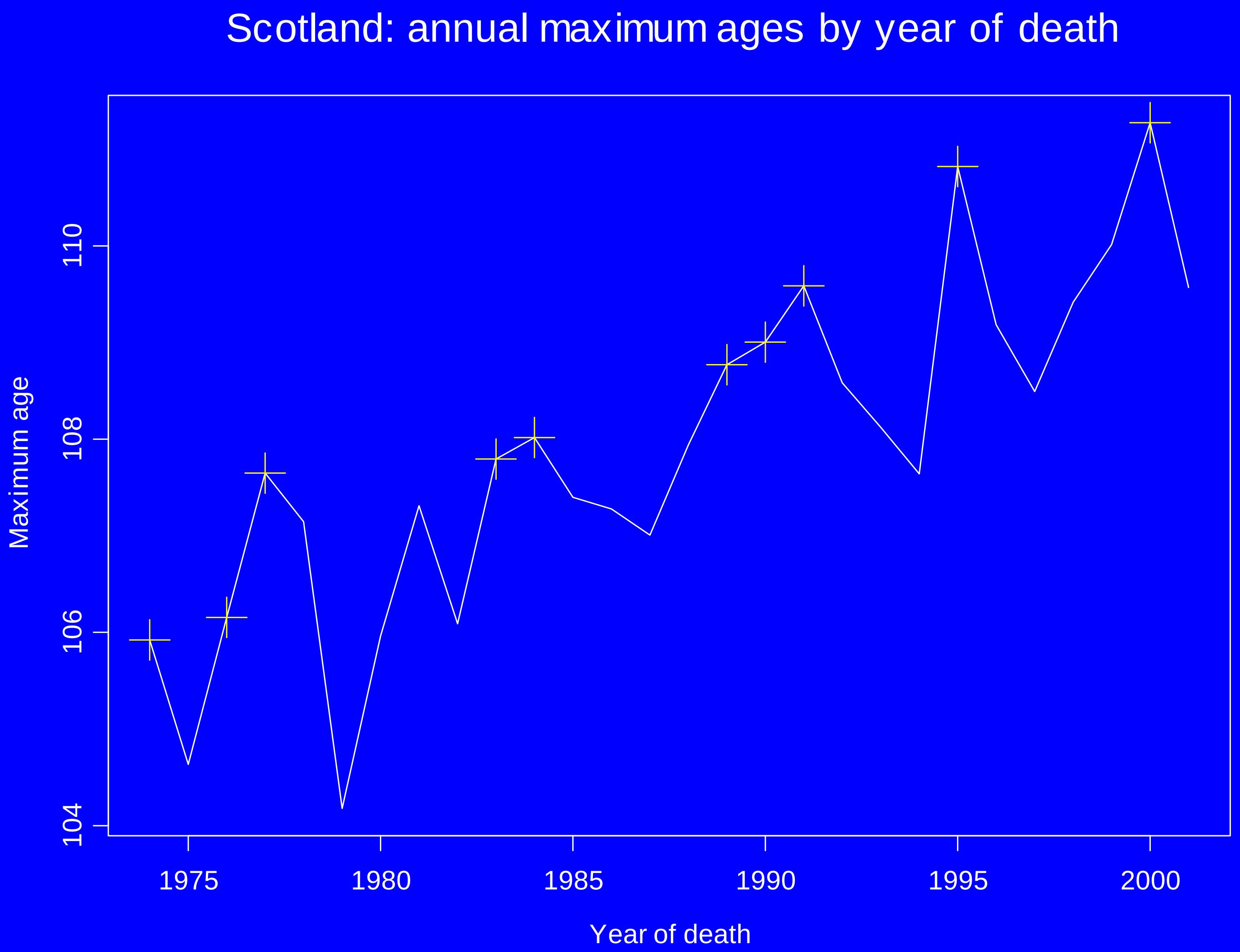
- Evidence points out to ongoing growth
- Why is it increasing?
  - Larger population sizes
  - Improvements in an individual's probability of survival at older ages
  - Mortality from most degenerative diseases (e.g. stroke and heart disease) has been falling since 1950's
  - From mid 1990's there's been a decrease in total cancer mortality in economically developed countries

Life expectancy forecasts for G7 countries in 2050

	Official	Revised	Gap
USA	80.45	82.90	2.5
Canada	81.67	85.26	3.6
Japan	82.95	90.91	8.0
France	83.50	87.01	3.5
Italy	82.50	86.26	3.8
UK	82.50	83.79	1.3
Germany	81.50	83.12	1.6

Source: Horiouchi, Nature (2000)

Records of maximum lifespans



Trends in record processes

Records model: $X_n = cn + Y_n, \quad c \geq 0, Y_n$ are i.i.d. r.v.

Define the record rate as $P(n) = \frac{M(n)}{n} = \frac{1}{n}\sum_{i=1}^{n} I_{A_j}$

where A_j is the event $\{X_j$ is a record$\}$

Then $P(n)$ is an indicator of trend c

If $c > 0, \lim_{n\to\infty} P(n) = p \in (0,1)$ a.s. and

$\sqrt{n}\left(P(n) - p\right) \xrightarrow{d} N(0, \sigma^2)$ as n $\to \infty$, where $\sigma^2 = p(1-p)$

Trends in records processes

This variance is unknown; we used the estimator

$$\hat{\sigma}_n^2 = \hat{\gamma}_n(0) + 2\sum_{k=1}^{m_1}\left(1 - k/n\right)\hat{\gamma}_n(k)$$

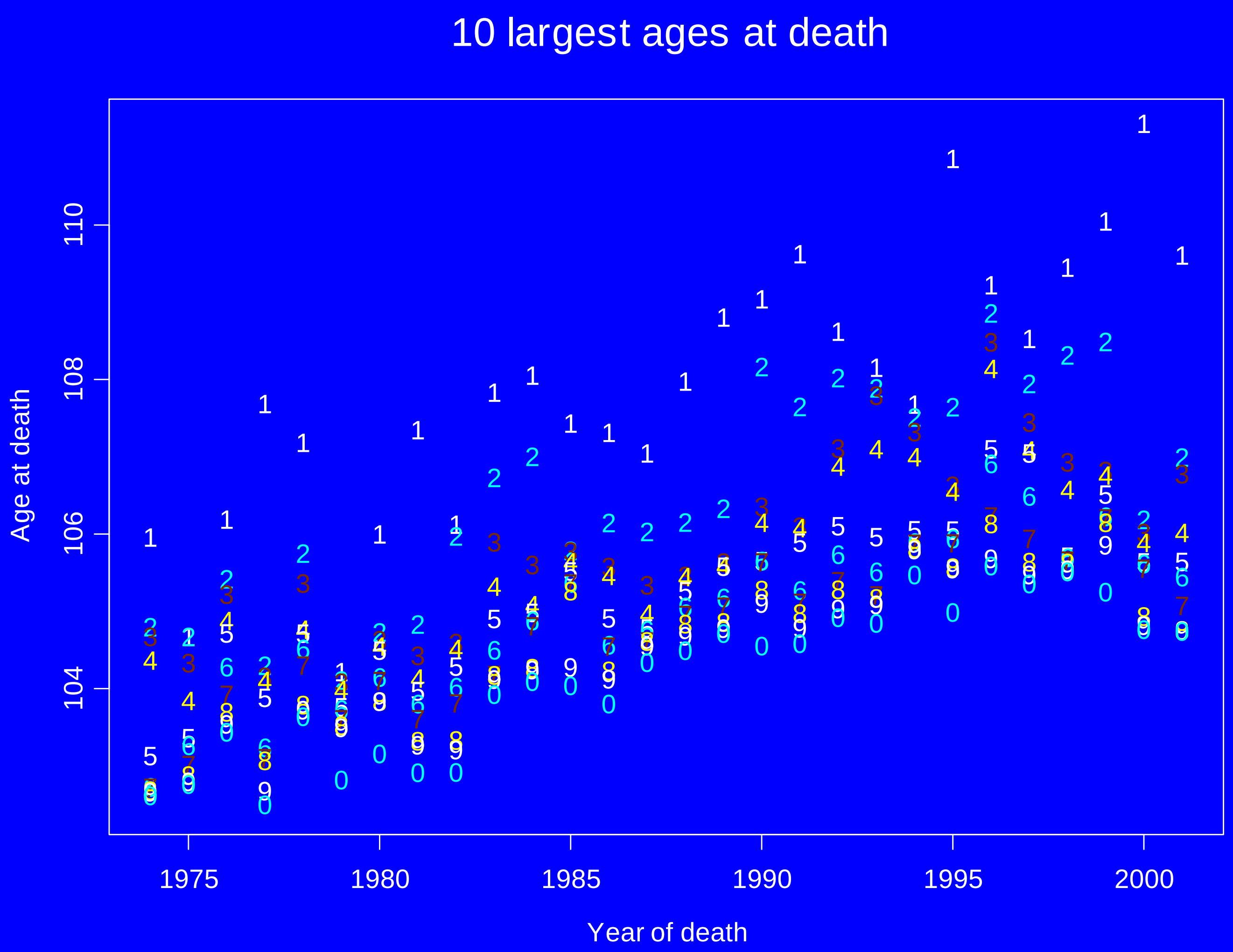
proposed by Ballerini & Resnick (1994)

where $m_1 = \left\lfloor \sqrt{\mathrm{n}} \right\rfloor$, and $\hat{\gamma}_n(k)$ is a consistent estimator of the autocovariance at lag k

The CI for p is then calculated using a Normal approximation; if it contains 0 then the trend is n.s.

For these data, $\hat{p} = 10/28 = 0.357, CI = (0.26, 0.45)$

Using the *r* largest order statistics and the GEV distribution



10-order stats GEV fit with linear and seasonal trend

	Intercept	Slope	Sine	Cosine	Scale	Shape
MLE	102.523	0.014	0.574	-0.104	1.625	-0.106
Std Error	0.184	0.001	0.129	0.132	0.069	0.033

Since the shape parameter is negative, extrapolations to any level would lead to a finite limit, though the trend is significant

CI's for seasonal relative risk

RR = maximum/minimum fitted frequency

Let $(n_1,...,n_{12})$ be monthly (31-day std) counts from a multinomial distribution with probabilities $(p_1,..., p_{12})$, such that $p_i = \exp\left[\gamma \cos\left(2\pi(i-\beta)/12\right)\right]$

Then $e^{2\gamma}$ is the relative risk (max freq/min freq) of the event, and β is the month of maximum frequency and $\gamma \geq 0$, $\beta \in \{1,2,...,12\}$

- This model is a discrete analogue of the circular Normal distribution for continuous data
- No seasonality is tested when all the multinomial probabilities are 1/12, i.e. with $\gamma = 0$

- This test is more powerful than one with a less structured model, i.e. fitting 11 probabilities

MLE for Relative Risks

Let $\left(\gamma^*, \beta^*\right)$ be the true values of the parameters

Want CI's for γ^* based on the MLE $\left(\hat{\gamma}, \hat{\beta}\right)$ obtained

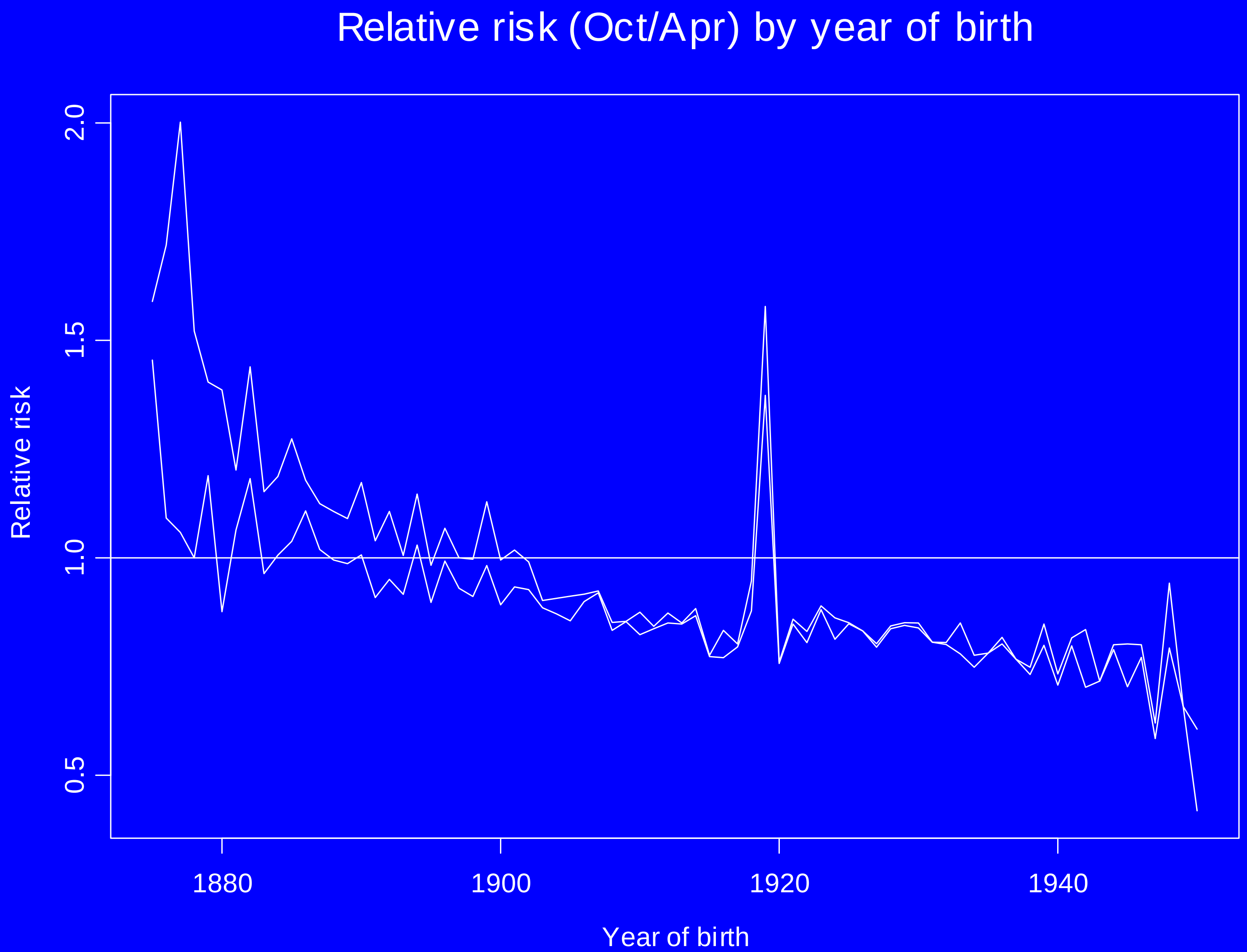
maximising:

$$L(\gamma, \beta) = \prod_{i=1}^{12} \left[p_i(\gamma, \beta) \right]^{n_i}, \text{ with}$$

$$p_i(\gamma, \beta) = \frac{\exp[\gamma \cos(2\pi(i - \beta)/12)]}{\sum_{j=1}^{12} \exp[\gamma \cos(2\pi(j - \beta)/12)]}$$

Note that since the null value, $\gamma = 0$ is a boundary value the usual theory for CI's of the form $\hat{\gamma} \pm z_{\alpha/2} s.e.(\hat{\gamma})$ is not applicable, though it's possible to obtain CI's using bootstrap

Deaths > 50, 1974-2001



The 1918-1920 "Spanish" Influenza Pandemic

- One of the largest outbreaks of infectious disease in recorded history occurring in a very short time
- There were two or three waves starting in the Northern spring and summer of 1918 persisting or ending by 1920
- Estimates vary: the latest calculation (Johnson & Mueller, Bull Hist Med 2002) suggests **at least** 50 million deaths

The 1918-1920 "Spanish" Influenza Pandemic

- Global epidemic – extremely virulent
- Heavy toll on young adults (20 – 40)
- Some regions had mortality rates as high as 5-10 percent
- First (mild) wave in spring/summer 1918
- Second in autumn 1918
- Third early in 1919
- Some regions had a further wave early in 1920

Mortality of the 1918-1920 Influenza Pandemic

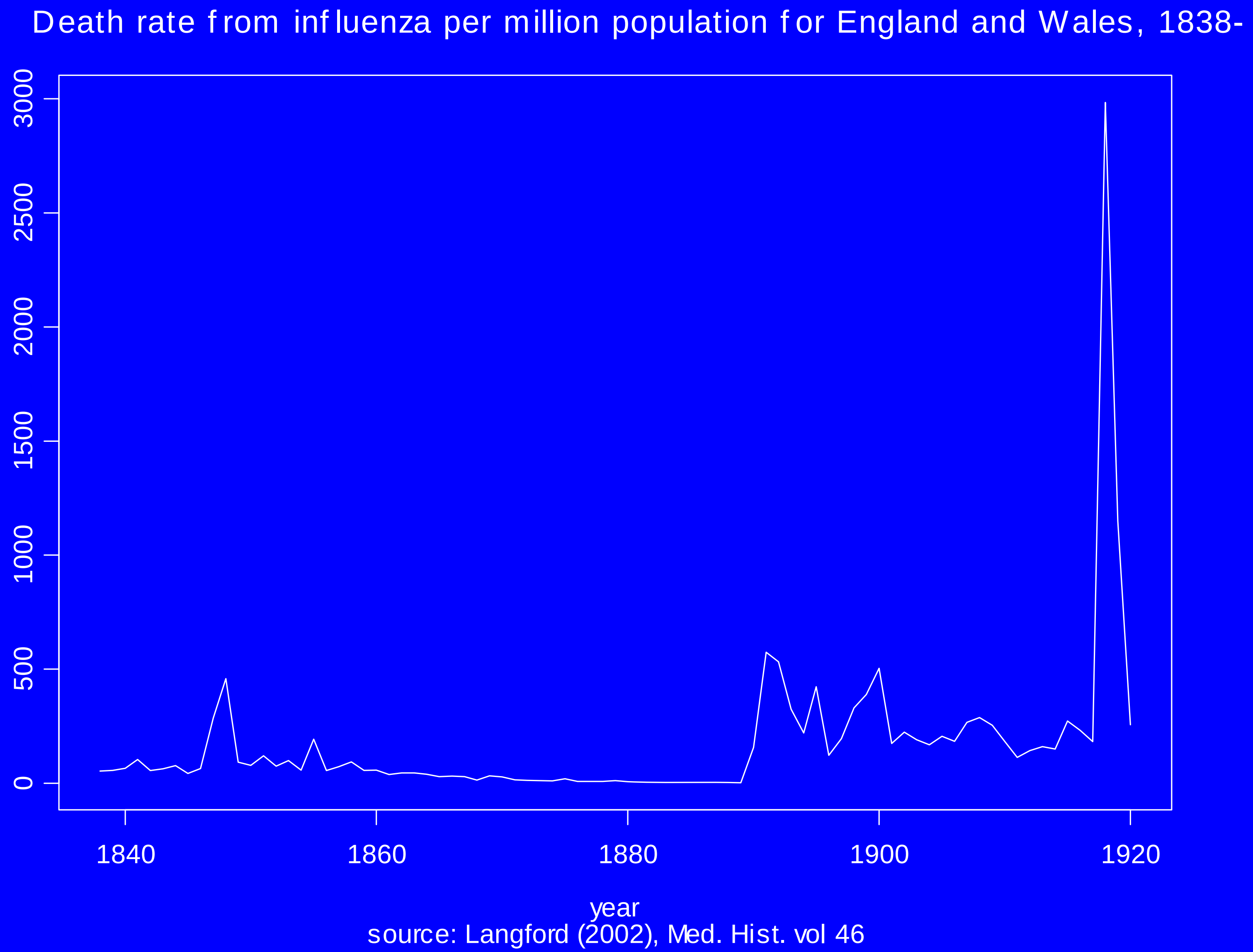
Africa	Pop (000s)	Deaths (000s)	America	Pop (000s)	Deaths (000s)
Egypt	12,936	138	Argentina	8,517	10
Kenya	2,596	150	Brazil	26,277	180
Nigeria	18,631	455	Canada	8,148	50
South Africa	6,769	300	Guatemala	1,241	49
			Mexico	14,556	300
			Uruguay	1,439	2
			USA	103,208	675

Asia	Pop (000s)	Deaths (000s)
Ceylon	5,109	92
China	472,000	4,000
India	305,693	18,500
Indonesia	49,350	1,500
Japan	55,033	388

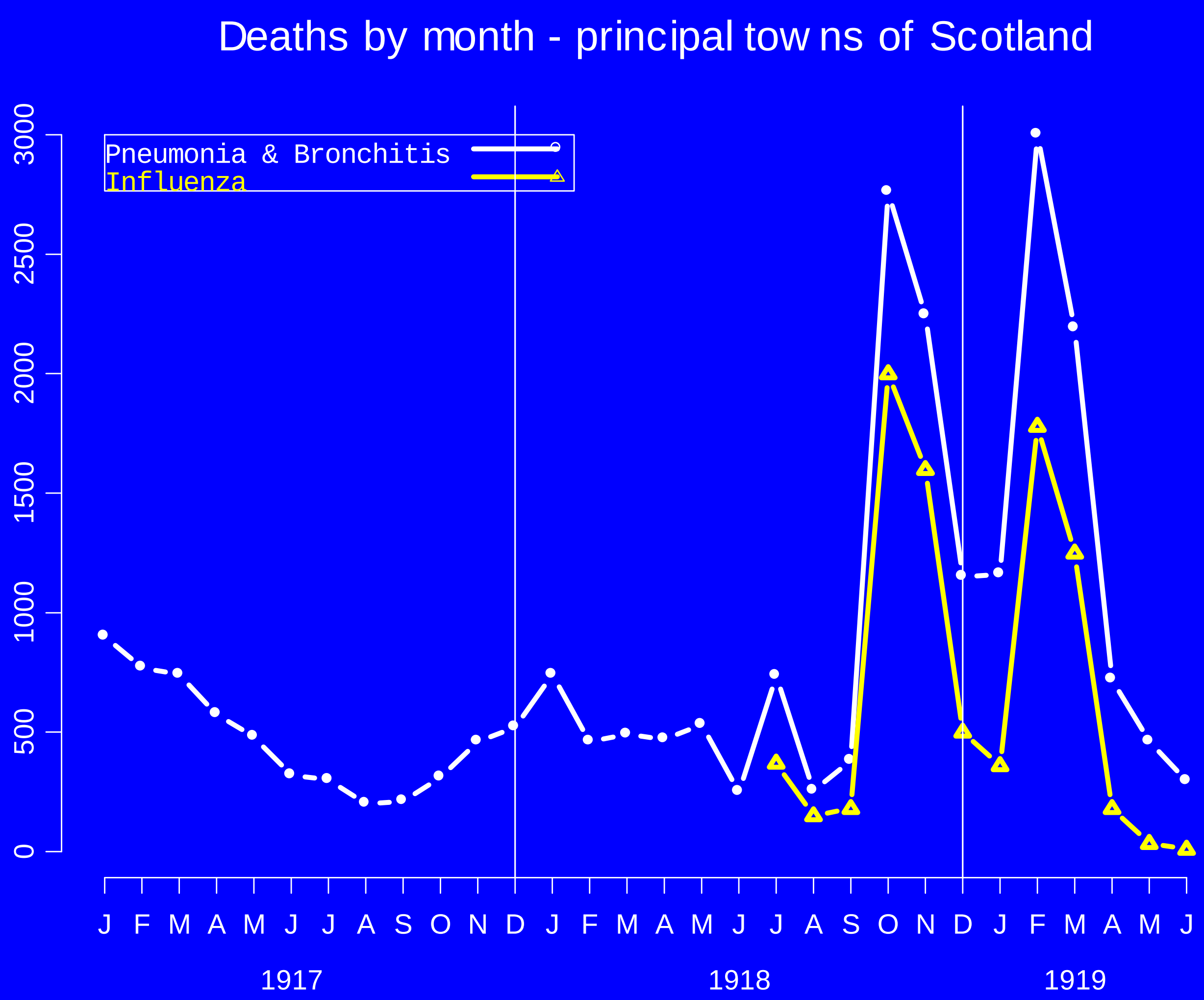
Oceania	Pop (000s)	Deaths (000s)
Australia	5,304	15
Fiji	164	9
New Zealand	1,158	9
Western Samoa	36	8.5

Europe	Pop (000s)	Deaths (000s)
England & Wales	34,020	200
France	32,830	240
Germany	58,450	225
Ireland	4,280	18
Italy	36,280	390
Netherlands	6,750	48
Scotland	4,850	30
Spain	20,880	257
Sweden	5,810	34
Switzerland	3,880	23

The 1918-1920 influenza pandemic



Influenza pandemic in Scotland, 1918-1919



Source: Annual report of the Registrar-General for Scotland, 1919

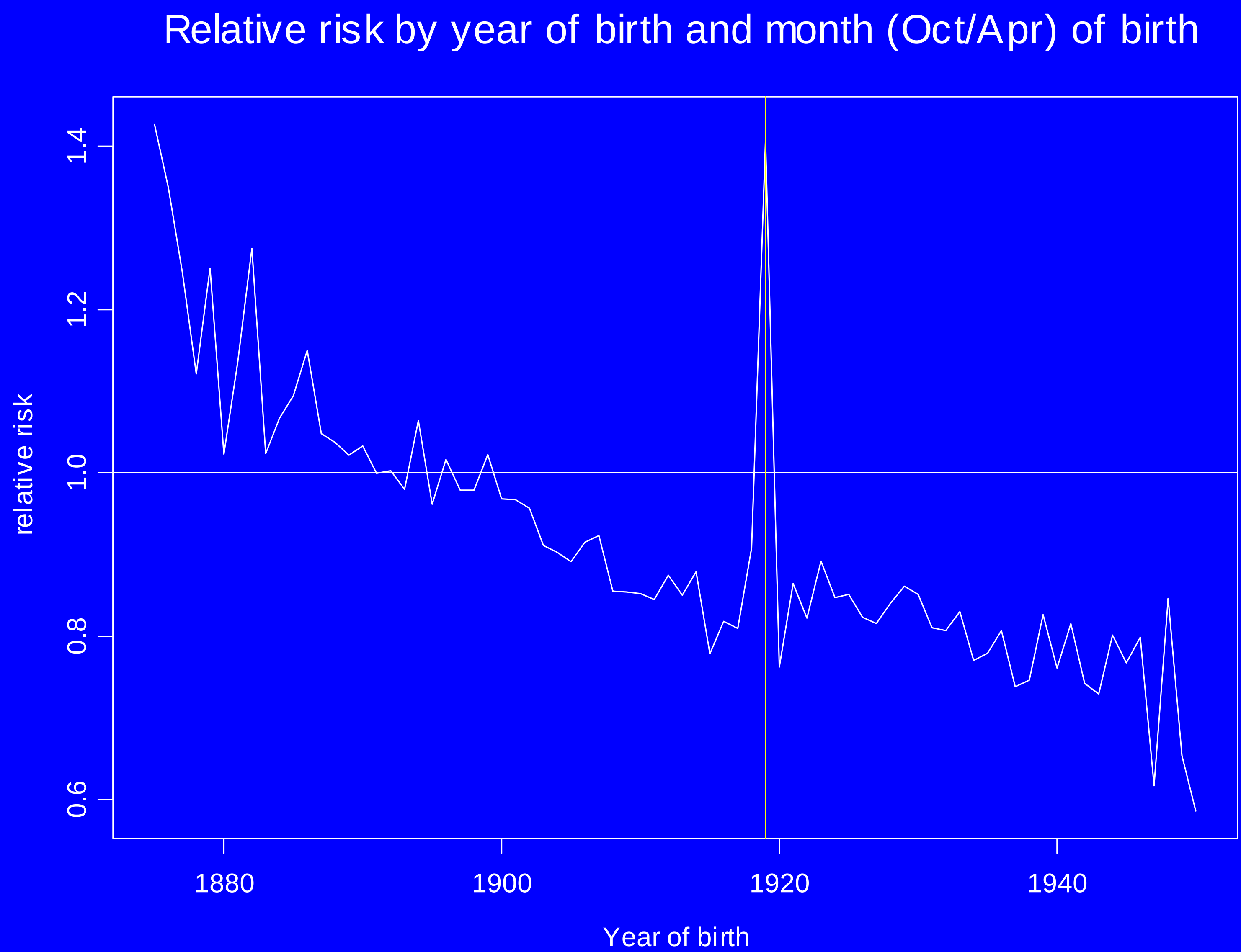
Scotland: Percentages of total deaths

Age group	Influenza 1918-1919	Influenza 1900	All causes 1917
< 1	4.09	4.94	15.07
1 to 4	10.21	2.62	10.43
5 to 9	4.47	0.70	2.45
10 to 14	3.50	0.77	1.69
15 to 24	15.12	3.58	4.78
25 to 34	23.56	3.80	5.07
35 to 44	11.40	6.42	5.80
45 to 54	9.42	8.93	9.04
55 to 64	7.52	15.20	12.57
65 to 74	6.71	23.83	15.53
≥ 75	4.00	29.21	16.53

Is being born in Autumn protective vs infectious disease?

- 2nd wave in Scotland = Sep 1918 – Dec 1918
- 3rd wave in Scotland = Jan 1919 – Apr 1919
- There is roughly the expected relative risk of deaths Oct/Apr for people born during the 2nd wave
- There were much more survivors (dying > 50) than expected born in Autumn 1919 than in Spring 1919 - though infant mortality due to influenza wasn't particularly bad

Deaths >50, 1974-2001



Future research

- Mortality in children, especially caused by accidents
- Analysis for specific causes of death
- Analysis by social class?
- Bigger databases: England & Wales?
  Mexico?

Acknowledgments

- The late Professor A.S. Douglas (Department of Medicine and Therapeutics, University of Aberdeen)
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