Supporting Information: Human Birth Seasonality: Latitudinal Gradient and Interplay with Childhood Disease Dynamics

Micaela Martinez-Bakker, Kevin Bakker, Aaron A. King, Pejman Rohani

December 18, 2013

S1 Materials & Methods

Birth Timing and Amplitude

In our analyses we followed the work of Rosenberg, who stated that adjusting for the differing number of days in each month had little effect on analyses of birth seasonality [1] . Thus, we did not make any adjustments of our time series to account for the different number of days in each month.

In the wavelet spectral analysis we tested for birth periodicity with periods ranging from 2 months to one-third the length of each data series. Since a significant 1 year period was observed, we constructed monthly phase angle time series for each data series using an 11-13 month period. The phase angle time series were subsequently used to determine the timing of the annual birth peak for each location. Peak-birth months were then averaged for each individual data series, with the U.S. states mapped to visualize the geographical variation in the timing of the annual birth peak. When biannual peak-births occurred in the U.S., they were separated into two 6 month periods: summer (May-Oct) and winter (Nov-April) (Figs. S1 & S2).

The analysis of seasonal birth amplitude, or percent deviation from the annual mean, was done using seasonally decomposed time series. The stl function in the stats package in R was used to decompose the data into seasonal ($\mathcal{S}$), trend ($\mathcal{T}$), and noise ($\mathcal{N}$) components for each data series. The noise free time series were constructed as:

$$\mathcal{F} = \mathcal{S} + \mathcal{T} \qquad \text{(Eqn. S1)}$$

The deviation from the mean during the birth peak was calcualted for each year, i, as:

$$x = \max(\mathcal{F}_i) - \text{mean}(\mathcal{T}_i) \qquad \text{(Eqn. S2)}$$

The deviation from the mean during the birth trough was calculated for each year, i, as:

$$y = \min(\mathcal{F}_i) - \text{mean}(\mathcal{T}_i) \qquad \text{(Eqn. S3)}$$

Thus, the one-half peak-trough difference is:

$$z = \frac{x - y}{2} \qquad \text{(Eqn. S4)}$$

The seasonal amplitude, measured as a percent deviation from the mean, was calculated as:

$$\text{amplitude} = \frac{z}{\text{mean}(\mathcal{T}_i)} \qquad \text{(Eqn. S5)}$$

Simulation study

For the simulation study we used a daily discrete-time SEIR model of measles adopted from Earn et al. 2000 [2]. The model has a daily time step and uses school-term forcing of seasonal transmission based on the school terms of England & Wales. The models assume transition probabilities follow a Poisson process. The difference equations are as follows:

$$S_{t+1} = \mu_t N_t + S_t e^{-(\beta_t I_t + \delta)} \qquad \text{(Eqn. S6)}$$

$$E_{t+1} = S_t \left(1 - e^{-(\beta_t I_t + \delta)}\right) \frac{\beta_t I_t}{\beta_t I_t + \delta} + E_t e^{-(\phi + \delta)} \qquad \text{(Eqn. S7)}$$

$$I_{t+1} = E_t \left(1 - e^{-(\phi + \delta)}\right) \frac{\phi}{\phi + \delta} + I_t e^{-(\gamma + \delta)} \qquad \text{(Eqn. S8)}$$

$$R_{t+1} = I_t \left(1 - e^{-(\gamma + \delta)}\right) \frac{\gamma}{\gamma + \delta} + R_t e^{-\delta} \qquad \text{(Eqn. S9)}$$

$$N_t = S_t + E_t + I_t + R_t \qquad \text{(Eqn. S10)}$$

$$Incidence_t = E_t \left(1 - e^{-(\phi + \delta)}\right) \frac{\phi}{\phi + \delta} \qquad \text{(Eqn. S11)}$$

$$\mu_t = \frac{\nu + A \sin(\omega t + \sigma)}{30} \qquad \text{(Eqn. S12)}$$

$$\beta_t = \frac{B_0}{\frac{1}{365}\left((1 + b_1)273 + (1 - b_1)92\right)} \left(1 + b_1 Term_t\right) \qquad \text{(Eqn. S13)}$$

$Term_t$ is based off the the school term schedule. When school is in session $Term_t = 1$ and when students are on holiday $Term_t = -1$. See Table S1 for the school term schedule. The parameter values used for the simulation study can be found in Table S2. All simulations were run for 100 - 150 yrs. to ensure that the trajectories were past the transient phase.

Table S1: School term schedule. When students are on holiday $Term_t = -1$ otherwise 1.

Holiday	*Model Days*	*Calendar Days*
Christmas	356 - 6	Dec 21 - Jan 6
Easter	100 - 115	Apr 10 - 25
Summer	200 - 251	Jul 19 - Sept 8
Autumn Half Term	300 - 307	Oct 27 - Nov 3

Table S2: Parameters used in simulation study, main text Figure 4A & 4B.

Parameter	*Value*	*Parameter*	*Value*
$\mathcal{R}_0$	16 (basic reproductive no.)	b_1	0.25
D	1 - 365 (birth peak day)	μ_0	$\frac{1}{18250}$ day^{-1}
δ	$\frac{1}{18250}$ day^{-1} (50 yr life span)	β_0	$\frac{\mathcal{R}_0}{5}$ day^{-1}
ϕ	$\frac{1}{8}$ day^{-1} (8 day latent period)	S_0	0.06
γ	$\frac{1}{5}$ day^{-1} (5 day infectious period)	E_0	0.001
ν	$\frac{30}{18250}$ month^{-1} (balances δ)	I_0	0.001
A	0 - 0.0009208 month^{-1} (0 - 56% birth amp.)	R_0	0.938
ω	$\frac{2\pi}{365}$ $\frac{\text{radians}}{\text{day}}$	N_0	$S_0 + E_0 + I_0 + R_0$
σ	$\frac{\pi}{2} - \frac{2\pi}{365}D$	$Incidence_0$	0
B_0	$\frac{\mathcal{R}_0}{5}$		

Inference study using simulated data

For the inference study we coupled our SEIR model (Eqs. S6 - S13) with a stochastic measurement model. The measurement model is as follows:

$$\text{cases}_t \sim \text{normal}(\rho Incidence_t, \rho\tau) \qquad \text{(Eqn. S14)}$$

In order to test whether the seasonality in births influences parameter estimation, we simulated case data using three parameterizations of our model, each differing in the timing of the birth peak. The parameters used to generate the data are given in Table S3. Simulations were run to year 50 to ensure the transient phase had passed.

Table S3: Parameters used to generate data for study, main text Figure 4C.

Parameter	*Value*	*Parameter*	*Value*
$\mathcal{R}_0$	$\frac{6250}{365}$ (basic reproductive no.)	b_1	0.25
D	162, 295, or 351 (birth peak day)	μ_0	$\frac{1}{18250}$ day^{-1}
δ	$\frac{1}{18250}$ day^{-1} (50 yr life span)	β_0	$\frac{\mathcal{R}_0}{5}$ day^{-1}
ϕ	$\frac{1}{8}$ day^{-1} (8 day latent period)	S_0	0.06
γ	$\frac{1}{5}$ day^{-1} (5 day infectious period)	E_0	0.001
ν	$\frac{30}{18250}$ month^{-1} (balances δ)	I_0	0.001
A	0.000456 month^{-1} ($\sim$ 28% birth amp.)	R_0	0.938
ω	$\frac{2\pi}{365}\ \frac{\text{radians}}{\text{day}}$	N_0	1
σ	$\frac{\pi}{2} - \frac{2\pi}{365}D$	$Incidence_0$	0
B_0	$\frac{\mathcal{R}_0}{5}$		

The three time series generated using the stochastic SEIR model were then fit to the SEIR model with a 0% birth amplitude, i.e. $A = 0$. The mean transmission rate, B_0, was the only free parameter. All other parameters, aside from A and B_0, were fixed at the values used to generate the data. Only the last 6 years of the time series were used for fitting, thus, the initial conditions were set to match those at the beginning of data used for inference.

For each time series B_0 was profiled and the likelihoods of the parameter sets with varying values of B_0 were calculated using a particle filtering in the R package pomp [3]. A particle filter (a.k.a. Sequential Monte Carlo) is a method of integrating state variables of a stochastic system and estimating the likelihood of the model for a fixed parameter set, given the data. However, since our model lacked process noise, we were able to obtain the exact likelihood for each parameter set.

Inference study using New York City measles data

For the New York inference study we utilized a Partially Observed Markov Process (POMP) model which are suited for dealing with epidemiological data where the state variables (susceptible, infected, recovered individuals) are not observed in the data, rather the infected individuals are partially observed through case reports [3]. For our process model we used a stochastic biweekly discrete-time SIR model. Similar to the model used for the simulation study, transitions were modeled using a Poisson process. The process model is as follows:

$$\lambda_t = \left(\beta_t \frac{I_t}{N_t} + \psi\right) \epsilon_t \qquad \text{(Eqn. S15)}$$

$$\varrho_t = e^{-dt(\lambda_t + \delta)} \qquad \text{(Eqn. S16)}$$

$$S_{t+1} = dtB_t + \varrho_t S_t \qquad \text{(Eqn. S17)}$$

$$I_{t+1} = (1 - \varrho_t)\, S_t \frac{\lambda_t}{\lambda_t + \delta} \qquad \text{(Eqn. S18)}$$

The transmission rate β_t was modeled using a periodic B-spline with 6 bases, a degree of 2, and a period of 1 year. The process noise ϵ_t was modeled as $\epsilon_t \sim \mathrm{normal}(1, \beta_{sd})$. The covariates B_t, monthly number of individuals entering the susceptible class, and N_t, population size, were taken from data. All parameters were estimated using iterated particle filtering [3] (discussed later), with the exception of the death rate which was fixed at $\delta = \frac{1}{600}\ month^{-1}$, i.e. 50 yr. life span, and $dt = \frac{1}{2}$ fixing the time step to biweekly. In order to couple our model with measles case data we overlaid the process model with a stochastic measurement model. The measurement model is as follows:

$$cases_t \sim \mathrm{normal}(\rho I_t, \tau I_t) \qquad \text{(Eqn. S19)}$$

The case data, gathered from [2], consisted of monthly measles cases for New York City from January 1949 - December 1962. Although we did not have birth data for New York City we did have per capita monthly births for the state of New York. Thus, we assumed the per capita monthly birth rate for New York City was equal to the per capita monthly birth rate for New York state. The population size of New York City was taken from the decadal census and the population size was interpolated for non-census years. Taking the New York City population size together with the time series of per capita monthly births we constructed a time series of the number of monthly births, $\mathcal{B}_t$, in New York City (not to be confused with B_t in Eqn. S17, which will be explained in the next section).

In order to test whether the seasonality in births influences model parameterization, we used four variants of our model (Eqn. S15-S18), each differing in the susceptible recruitment covariate, B_t. The first three models contain birth seasonality and account for the existence of maternal antibodies for 3-9 months. Whereas, in the fourth model we removed the birth seasonality. The first model variant lags the births by 3 months to account for a scenario where maternal antibodies confer protection from measles for the first 3 months of life:

$$B_t = \mathcal{B}_{t-3} \qquad \text{(Eqn. S20)}$$

In the second model variant we lag births by 6 months.

$$B_t = \mathcal{B}_{t-6} \qquad \text{(Eqn. S21)}$$

In the third model variant we lag births by 9 months.

$$B_t = \mathcal{B}_{t-9} \qquad \text{(Eqn. S22)}$$

In the fourth model variant we removed the seasonality of births by making the monthly births constant within each year by setting them equal to the mean monthly births for the year:

$$B_t = \frac{\sum_{i=1}^{12} \mathcal{B}_{i,j}}{12}; j \in [1948 : 1962], \qquad \text{(Eqn. S23)}$$

where i is the month and j is the year.

Each of the four model variants were independently fit to the data using Maximization by Iterated particle Filtering (MIF) using the R package POMP. MIF is a state-of-the-art simulation based method for parameter estimation that uses likelihood as the objective function. The basis of MIF is particle filtering (a.k.a. Sequential Monte Carlo), which is a method of integrating state variables of a stochastic system and estimating the likelihood of the model for a fixed parameter set, given the data. Unlike particle filtering, which uses fixed parameter values, MIF varies parameter values throughout the filtering process and selectively propagates particles (in the simplest sense, parameter sets) that have the highest likelihood. Thus, by initializing MIF throughout parameter space one can get a picture of the likelihood surface and identify the maximum likelihood parameter combinations within that space. For each of our models, MIF was initialized with 80000 parameter sets generated using a Sobol design, which pseudo-randomly samples parameters across parameter space in order to evenly sample the space. After this initial phase of MIF, parameter sets were passed through 15 successive stages of MIF, which included profiling. In total, for each model MIF was initialized at over 424000+

locations in parameter space to estimate the shape of the likelihood surface and identify the maximum likelihood parameter set(s). Table S4 provides the maximum likelihood estimate (MLE) parameter set for each model.

S2 Results.

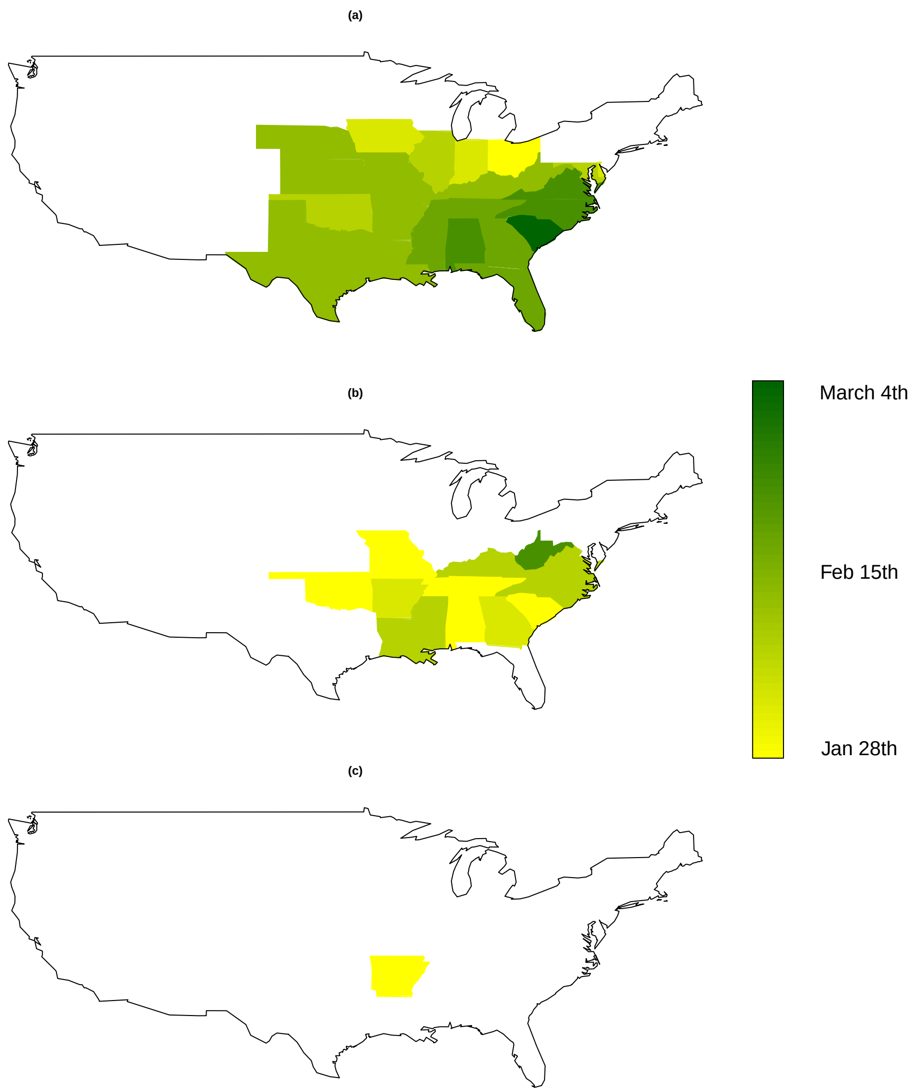
Detailed Results

Biannual birth pulses. During the pre-baby boom and baby boom eras, we found that some states had two birth pulses per year, i.e. they had a significant biannual period. All states significant for the biannual period were clustered together in the lower-midwest, deep south, and southeast (Figs. S1 & S2). In the baby boom era, some of the states lost their significant biannual period and transitioned to having only a single seasonal birth pulse (Figs. S1, & S2). In the modern era, Arkansas remained the only state with a biannual period. The clustering of the states with a significant 6 month period in the southeastern U.S. may have been due to now defunct cultural factors (Figs. S1 & S2).

Birth rates. Raw birth rates in the pre-baby boom era ranged from 0.89/1000/month in Nevada (February, 1936) to 2.80/1000/month in New Mexico (May, 1932), with the mean and median both approximately 1.60/1000/month; while in the baby boom era Maryland had the lowest birth rate at 1.13/1000/month (April, 1950), New Mexico with the highest birth rates at 3.36/1000/month (October, 1946), and the mean and median both approximately 2.04/1000/month. In the present period Vermont had the lowest birth rate at 0.67/1000/month (July, 2005), and Utah had the highest at 2.61/1000/month (July, 1977) with the mean and median falling in around 1.27/1000/month. Worldwide birth rates were not calculated, because we did not have population size data for our 200+ countries, rather raw birth values per month were used for wavelet spectral analysis. See Figure S3 for maps of the mean birth rates in each state and each era.

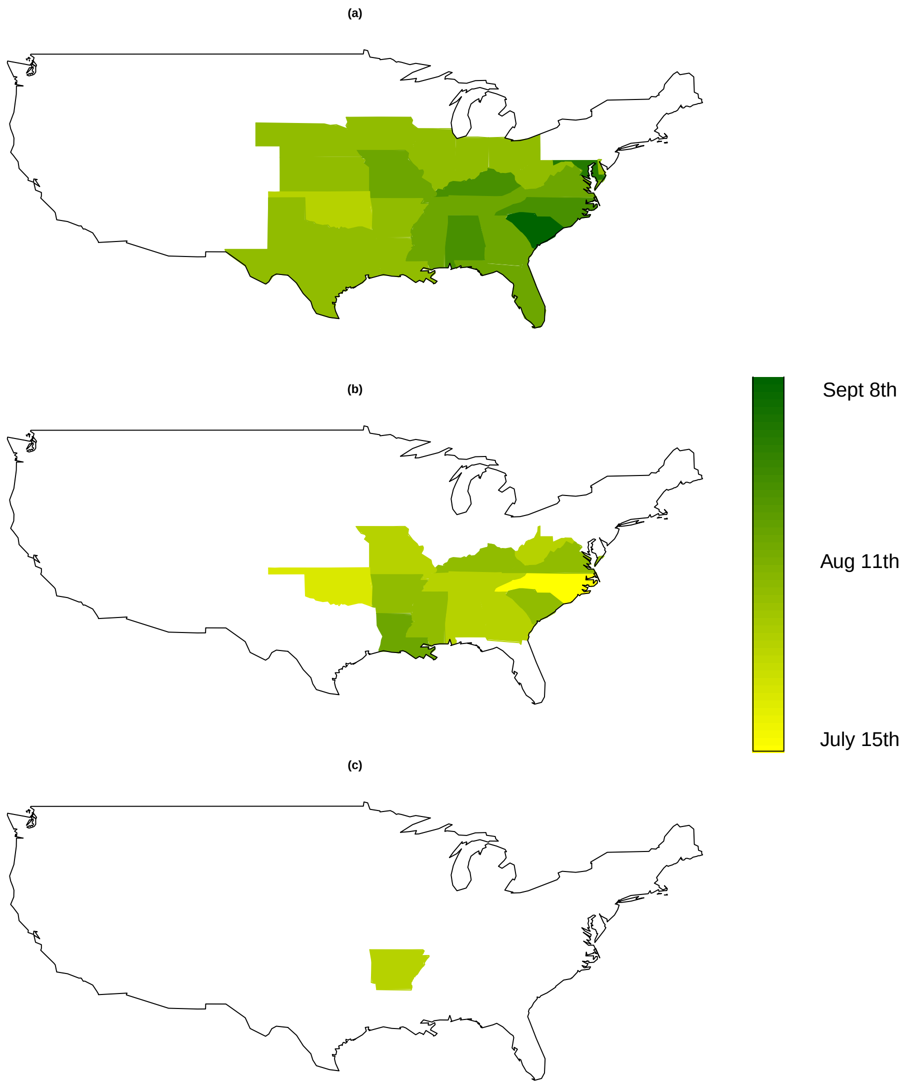
The seasonal birth pulse. Examining the phase angle time series at a period ranging from 11-13 months, the U.S. data had twenty four states significant in the pre-baby boom era, whereas all were significant in the baby boom and present eras. Of the 210 worldwide data series analyzed, 132 (63%) were significant at an 11-13 month period. Many of those found insignificant were shorter time series (5-7 years) or countries with extremely low birth values (<100 individuals/month). Those states and countries found to be significant were then analyzed for the timing of the peak birth month using a wavelet spectral analysis.

U.S. timing of the seasonal birth peak. During the pre-baby boom era, of the states with a significant 1 year period, Oregon (June 12th) and Maine (June 10th) had the earliest peak birth timing —excluding New Mexico, which is an outlier because it has an early peak in



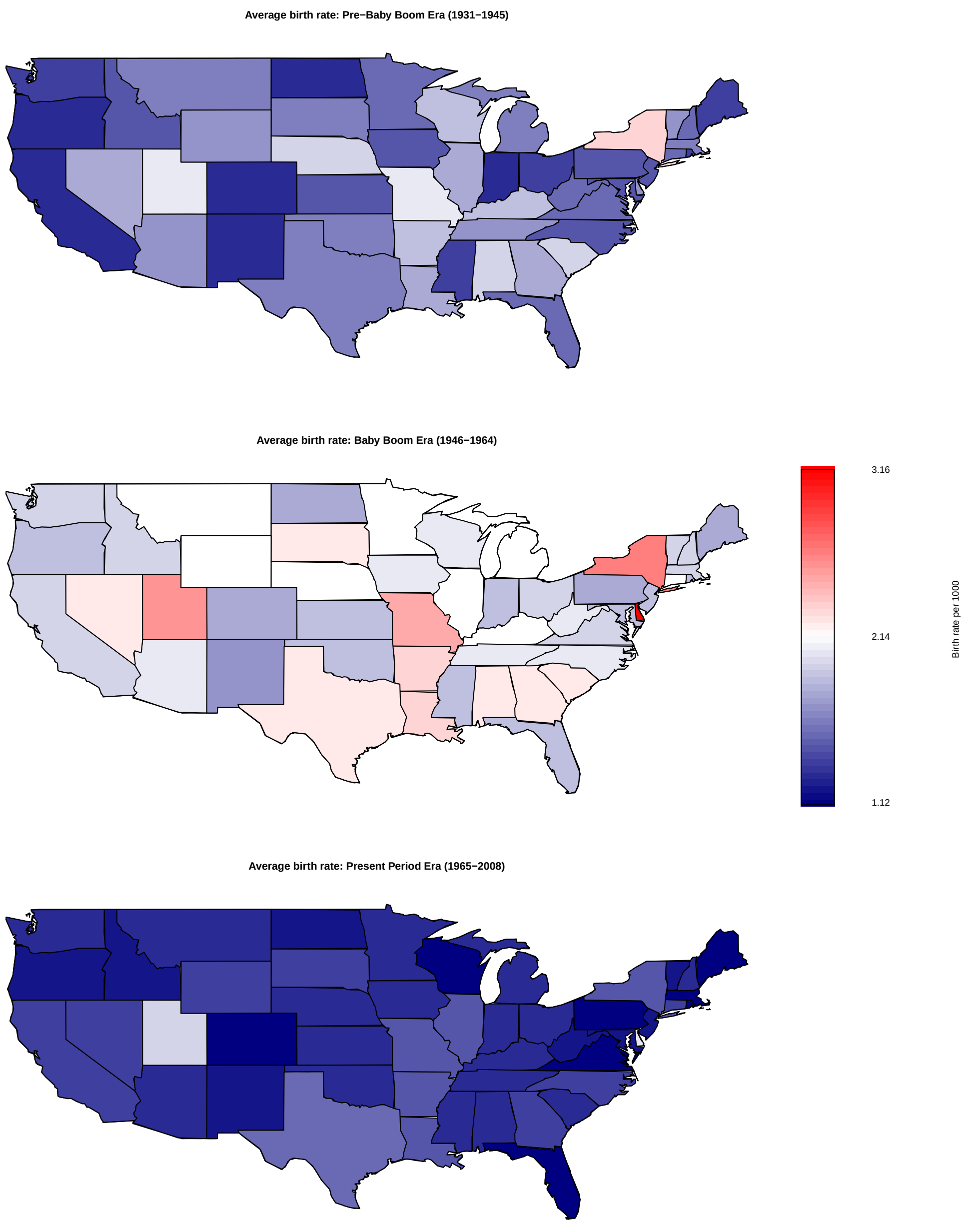
Supplementary Figure S1: Bi-annual winter (November-April) birth peak timing by period. (a) pre-baby boom (1931-1945), (b) baby boom (1946-1965), and (c) present period (1965-2008). States shown in white were not significant.

all eras yet is located in the southern U.S. Florida (Nov 10th) had the latest peak birth timing in early November. The median peak birth timing was July 3rd, and the mean was July 26th. The range of peak birth timing was at a maximum in the pre-baby boom era with a length of 156 days, approximately 5 months. In this era there was a subtle pattern in the birth peak

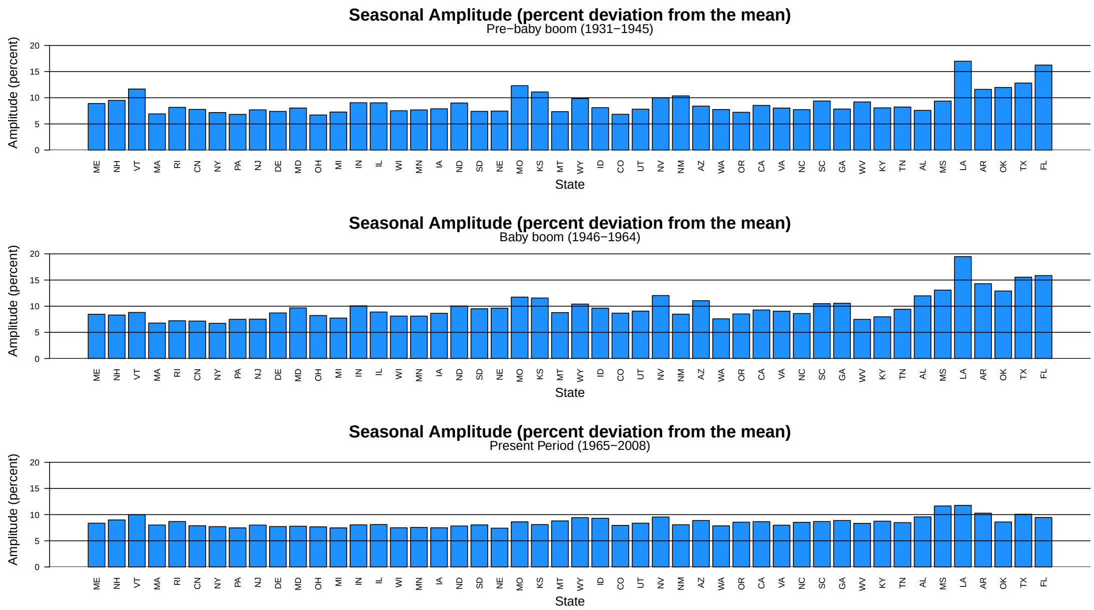


Supplementary Figure S2: Bi-annual summer (May-October) birth peak timing by period. (a) pre-baby boom (1931-1945), (b) baby boom (1946-1965), and (c) present period (1965-2008). States shown in white were not significant.

timing, with the northeast and northwest having earlier peaks than that of the deep south, the southeast and California.



Supplementary Figure S3: Maps of mean birth rates for each state, in each era. Top to bottom: pre-baby boom, baby boom, and present era. No geographic pattern could be easily discerned.



Supplementary Figure S4: Seasonal amplitude of births in U.S. states during each era. Note the high amplitude in the southern states (far right in all panels).

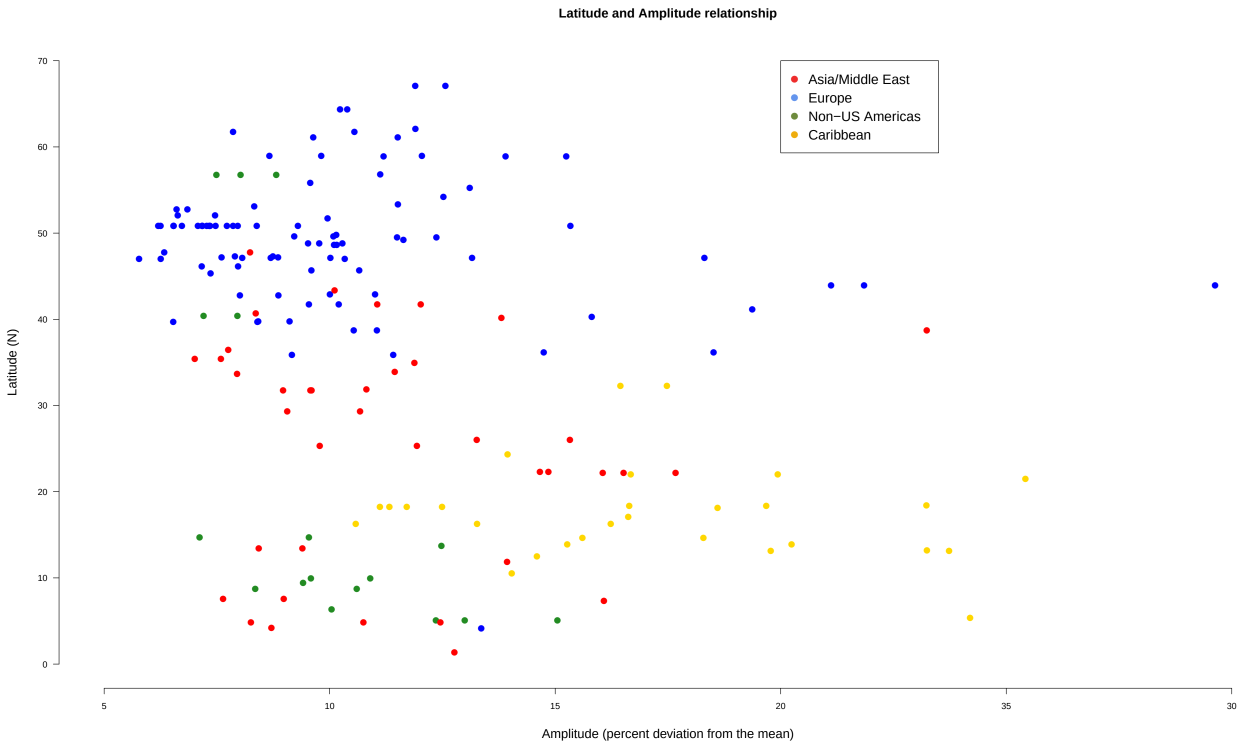
In the baby boom era, when all states were significant at the 1 year period, there was a clear latitudinal gradient in birth amplitude and peak birth timing. Northern states saw an earlier peak birth timing; Utah beginning with a peak birth timing in mid-July (July 13th), followed by Washington with a peak birth timing a few days later (July 18th) with no other peak birth timing occurring for at least another week after that. Again, Florida had the latest peak birth timing 3 months later in mid-October (Oct 21st). The mean (Sept 4th) and median (Sept 8th) both occurred in early September. In the baby boom era, other than Maine and those states already mentioned, the only states to have a peak prior to August 1st were also located in the northwestern U.S. (Idaho, Montana, North Dakota, and Oregon).

In the modern era, the spatial pattern of peak births was further elucidated with the mid-latitude states acting as a gradient for the northern and southern states. Utah again had the earliest peak birth timing in late June (June 26th), while Florida had the latest peak birth timing in early October (Oct 5th). The mean (Aug 11th) and median (Aug 7th) in this era both occurred in early August. Maine and Vermont also had peak birth timing prior to July 15th, which were the earliest peaks east of the Rocky Mountains. As with the baby boom era, many of the northwest states (Utah, Idaho, Montana, Oregon, Washington, and Wyoming) had peaks prior to July 15th in the present era. Over all eras, Florida consistently had the latest peak ranging from early October in the present period, to early-November in the pre-baby boom era.

Worldwide timing of the seasonal birth peak. The worldwide birth peak timing followed a similar pattern as observed in the U.S., with countries at higher latitudes having an earlier birth peak than those closer to the equator. The earliest peak was in Italy during the period 1970-1985 (March 22nd) followed closely by Tajikstan in the period 1989-1994 (April 15th). The latest birth peak occurred in Saint Vincent and the Grenadines during the period 1992-2005 (November 17th). The mean worldwide peak (U.S. states not included) was mid-August (August 17th). The overall pattern is clear, with Europe (high latitude) having an earlier birth peak, and the Caribbean having a later peak. Both the Asian/Middle Eastern and Non-U.S. data are difficult to categorize as they span broad geographical ranges.

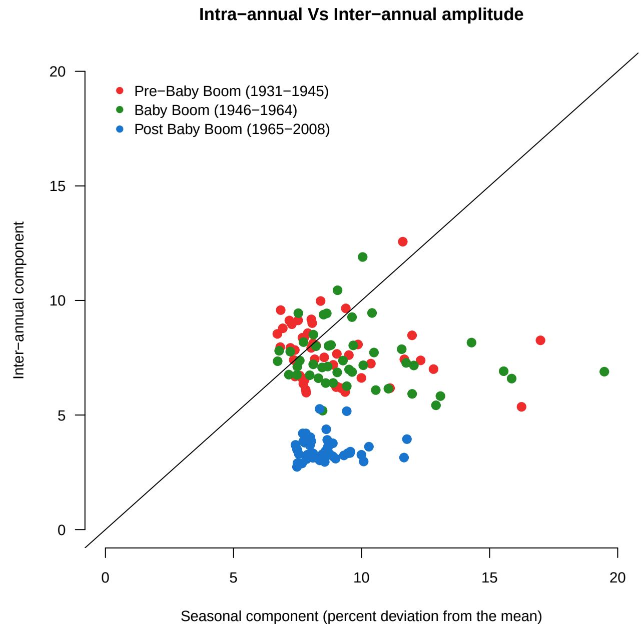
Seasonal birth amplitude. In the U.S., the largest seasonal amplitude in the pre-baby boom era was 20% from the mean (Louisiana, 1945), and the minimum was 4.2% from the mean in 1931 South Dakota (Fig. S4 top panel). These values increased during the baby boom era with a maximum 21.3% variation from the mean (Louisiana, 1954), and a minimum of 5.5% (Connecticut, 1957) (Fig. S4 middle). In the modern era, the maximum variation from the mean dropped to 17.4% (Louisiana, 1965) with the minimum staying relatively similar 5.4% (Delaware, 2004) (Fig. S4 bottom). The mean percent deviation from the mean in all states during the pre-baby boom era was 9.0%, 9.8% during the baby boom, and 8.5% in the modern era.

As shown in the main text Figure 2, we observed a latitudinal gradient in the seasonal birth amplitude in each era in the U.S. However, the latitudinal gradient in birth amplitude was not observed outside of the U.S. (Fig. S5). European seasonal amplitudes tended to be low, with a mean of 10.3%. Non-U.S. Americas had an approx. 9.8% amplitude, Asian/Middle Eastern countries having approx. 12.6%, and Caribbean countries approx. 17.2% (Fig. S5). However, due to the high variation in countries grouped into regions it is difficult to draw any conclusions from this.



Supplementary Figure S5: Seasonal (intra-annual) amplitude of northern hemispheric data plotted vs latitude.

Intra- vs. inter-annual variation in birth rates. We examined the seasonal (intra-annual) variation in births and compare that to the inter-annual variation (percent change from one year to the next) for each state in every era. We found that the seasonal (intra-annual) variation is generally larger (Fig. S6), with the intra-annual variation in the modern era 2-3 times larger than the inter-annual value.

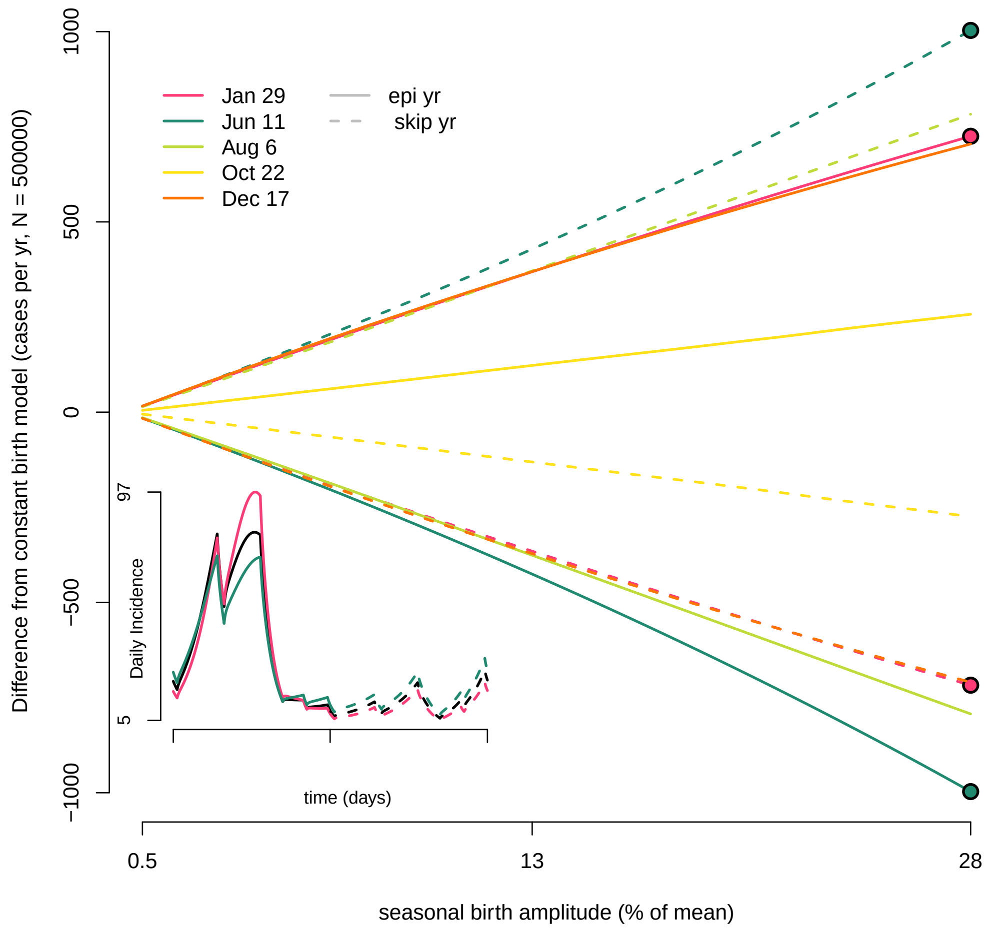


Supplementary Figure S6: The seasonal (intra-annual) amplitude vs the annual (inter-annual) amplitude. In both the pre-baby boom and baby boom most states had a stronger seasonal component, whereas in the present period all states have a stronger seasonal component.

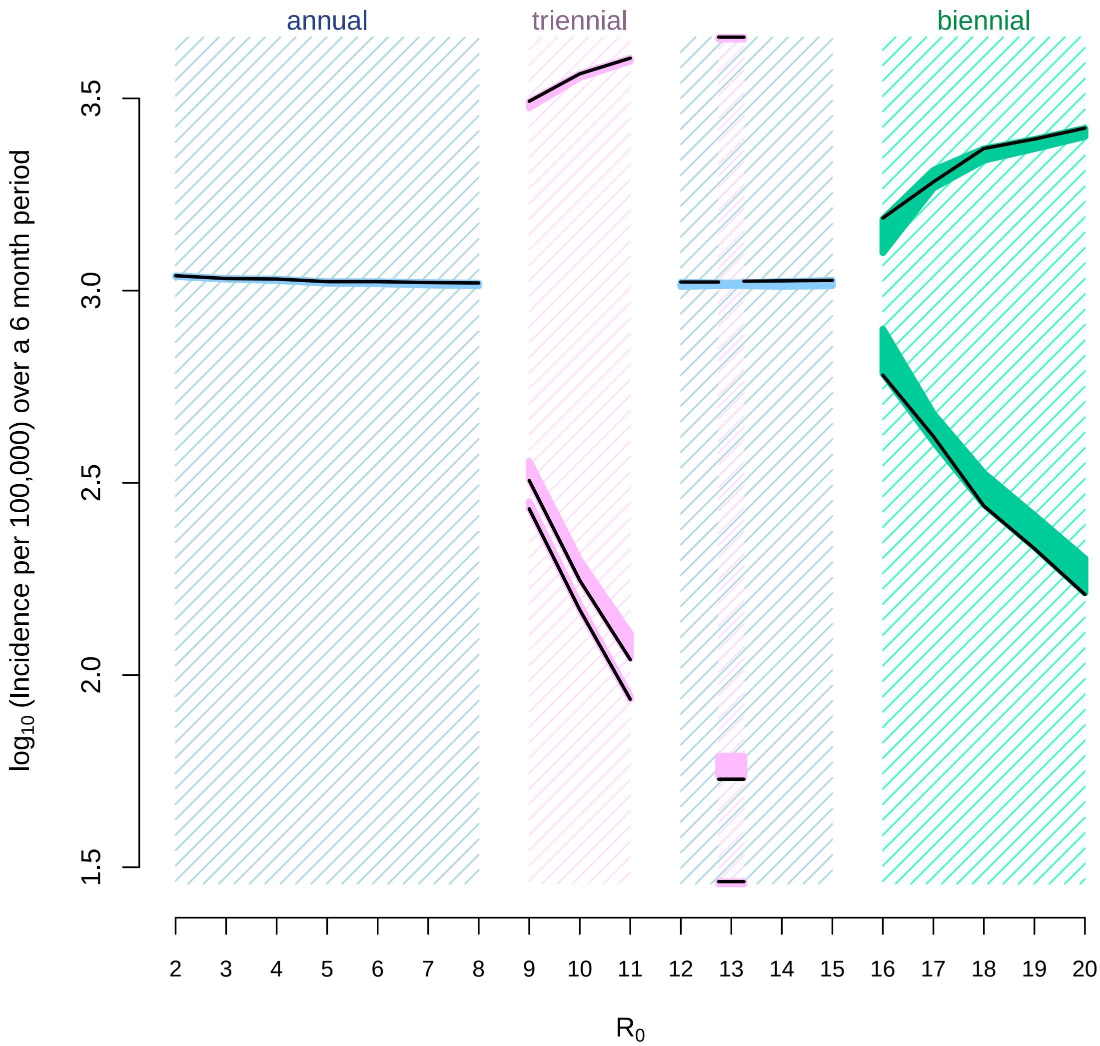
Simulation study

Fig. S7 shows the effect of increasing birth amplitude on measles incidence with the birth peak occurring at various times of the year. The difference in incidence resulting from measles models with either constant births or seasonal births increases with birth amplitude. However, depending on the phase relationship between peak susceptible recruitment (i.e. the birth peak) and the peak in seasonal transmission, birth seasonality can have the effect of either enhancing or dampening the epidemic year incidence.

Fig. S8 shows the effect of birth seasonality for various values of $\mathcal{R}_0$. Birth seasonality in this range of amplitude, $< 28\%$, has a pronounced effect on incidence when epidemics are biennial or triennial, as opposed to annual.



Supplementary Figure S7: Effect of increasing seasonal birth amplitude on measles incidence. The main graph show the change in epidemic and skip year incidence as a function of birth amplitude for 5 different phases of births seasonality. Phases were set such that the birth peak occurred in either Jan, Jun, Aug, Oct, or Dec. The turquoise and the fuschia points in the main graph correspond to the turquoise and fuchsia time series in the inset. Here $\mathcal{R}_0 = 17$ and the birth amplitude ranged from 0-28%, all parameters are those from Table S2.



Supplementary Figure S8: The effect of birth seasonality on diseases with varying basic reproductive numbers ($\mathcal{R}_0$). This is a bifurcation diagram our SEIR model with varying $\mathcal{R}_0$ and varying seasonal birth amplitude. The black lines are the incidence for the model with no birth seasonality (i.e. birth amplitude = 0%). The solid shaded intervals indicate the regions containing the incidence of the model with seasonal births, where the birth peak is in early June and the amplitude ranges from 1.4 - 27.7%. Birth seasonality in this range of amplitude has a pronounced effect on incidence when epidemics are biennial or triennial, as opposed to annual. Here $\mathcal{R}_0 \in [2:20]$, and $S_0 = 1/\mathcal{R}_0$, otherwise all other parameters are those in Table S2.

Inference study using New York City measles data

Maximum likelihood parameter estimates were obtained for each of our four measles models: seasonal births with a lag of 3 months from birth to susceptible to account for maternal antibodies, seasonal births with a lag of 6 months, seasonal births with a lag of 9 months, and constant births throughout the year.

Table S4: Maximum likelihood parameter estimates for each model. Rates are given in units of $month^{-1}$. All parameters were estimated using MIF with the exception of δ and dt, which were fixed. Note, $\mathcal{R}_0$ is the basic reproductive number and R_0 is the initial number of recovered individuals.

Parameter	*Model Seas-3*	*Model Seas-6*	*Model Seas-9*	*Model NoSeas*
$LogLikelihood$	-1080.99 ± 0.20	-1080.86 ± 0.12	-1081.14 ± 0.12	-1080.95 ± 0.14
$\mathcal{R}_0$	19.3	19.5	20.3	19.7
β_{coef_1}	55.4	55.6	58.9	56.5
β_{coef_2}	45.8	47.2	48.6	46.8
β_{coef_3}	45.6	45.5	48.5	47.8
β_{coef_4}	44.0	44.2	46.8	45.3
β_{coef_5}	17.5	18.5	18.7	18.3
β_{coef_6}	28.7	27.6	28.3	27.7
ψ	3.4×10^{-4}	3.8×10^{-4}	4.2×10^{-4}	4.1×10^{-4}
β_{sd}	0.121	0.118	0.121	0.124
dt	1/2	1/2	1/2	1/2
δ	1/600	1/600	1/600	1/600
ρ	0.238	0.236	0.239	0.238
τ	3.8×10^{-2}	3.8×10^{-2}	3.9×10^{-2}	3.8×10^{-2}
S_0	819214	947306	937014	1719583
I_0	16602	22758	17265	27629
R_0	6238289	6104041	6119826	5326893

References

[1] Rosenberg, H. M., 1966 Seasonal Variation of Births United States, 1933-63. *National Center for Health Statistics* **21**, 1–59.

[2] Earn, D. J., Rohani, P., Bolker, B. M. & Grenfell, B. T., 2000 A Simple Model for Complex Dynamical Transitions in Epidemics. *Science* **287**, 667–670. ISSN 0036-8075.

[3] King, A. A., Ionides, E. L., Bretó, C. M., Ellner, S., Kendall, B., Wearing, H., Ferrari, M. J., Lavine, M. & Reuman, D. C., 2010 *POMP: Statistical Inference for Partially Observed Markov Processes (R package)*.

Table S5: Data used in national-level analyses of birth seasonality. Significance refers to the annual period. Mean birth peak timing and amplitude were estimated from the data.

Country	Years	No. Years	Latitude	Mean peak month	Significant	Group	Amplitude
Albania	1981-2007	27	41.17	6.15	Yes	Europe	19.37%
Algeria	1998-2002	5	33.10	8.80	No	Africa	10.11%
American Samoa	1984-1988	5	-14.30	5.20	Yes	Asia	14.77%
American Samoa	1996-2006	11	-14.30	4.45	Yes	Asia	14.81%
Antigua and Barbuda	1979-1986	8	17.05	10.50	Yes	Caribbean	16.62%
Armenia	1987-1999	13	40.29	7.31	No	Europe	15.81%
Aruba	2002-2007	6	12.52	9.17	Yes	Caribbean	14.60%
Australia	1973-2008	36	-32.35	6.56	No	Asia	6.06%
Austria	1973-2011	38	47.77	6.50	Yes	Europe	6.33%
Azerbaijan	1992-2004	13	40.18	2.31	No	Asia	13.81%
Bahamas	1972-1979	8	24.32	10.50	Yes	Caribbean	13.95%
Bahrain	1975-1985	11	26.03	6.09	No	Asia	15.33%
Bahrain	1986-2002	17	26.03	10.35	Yes	Asia	13.26%
Barbados	1969-1976	7	13.16	7.86	No	Caribbean	23.73%
Barbados	1982-1991	10	13.16	11.00	Yes	Caribbean	19.78%
Belarus	1987-1999	13	53.33	5.31	Yes	Europe	11.52%
Belgium	1971-1995	25	50.84	6.08	Yes	Europe	7.18%
Belgium	1998-2008	11	50.84	7.64	No	Europe	6.54%
Belgium-Bruxelles	1998-2008	11	50.84	8.09	No	Europe	7.35%
Belgium-Flamande	1998-2008	11	50.84	6.73	No	Europe	6.54%
Belgium-Anvers	1998-2008	11	50.84	6.64	No	Europe	7.33%
Belgium-Limbourg	1998-2008	11	50.84	6.45	No	Europe	7.96%
Belgium-Flandreorientale	1998-2008	11	50.84	7.18	No	Europe	6.25%
Belgium-Brabantflamand	1998-2008	11	50.84	6.91	Yes	Europe	7.47%
Belgium-Flandreoccidentale	1998-2008	11	50.84	5.64	No	Europe	7.17%
Belgium-Wallonne	1998-2008	11	50.84	8.55	Yes	Europe	6.73%
Belgium-Germanophone	1998-2008	11	50.84	5.18	No	Europe	15.34%
Belgium-Brabantwallon	1998-2008	11	50.84	6.91	Yes	Europe	7.86%
Belgium-Hainaut	1998-2008	11	50.84	9.09	Yes	Europe	6.20%
Belgium-Liege	1998-2008	11	50.84	8.27	No	Europe	7.08%
Belgium-Luxembourg	1998-2008	11	50.84	8.55	Yes	Europe	8.38%
Belgium-Namur	1998-2008	11	50.84	8.91	Yes	Europe	7.27%
Bermuda	1984-1991	8	32.30	9.38	Yes	Caribbean	17.48%
Bermuda	1995-2001	7	32.30	9.00	Yes	Caribbean	16.45%
BVI	1980-1986	7	18.43	10.43	Yes	Caribbean	23.23%
Brunei Darussalam	1972-1976	5	4.82	8.00	No	Asia	12.46%
Brunei Darussalam	1980-1992	13	4.82	9.31	No	Asia	10.75%
Brunei Darussalam	1996-2002	7	4.82	9.71	Yes	Asia	8.26%
Bulgaria	1973-1978	6	42.75	4.83	No	Europe	8.01%
Bulgaria	1980-1990	11	42.75	6.18	Yes	Europe	8.87%
Canada	1973-1990	18	56.76	6.06	Yes	Americas	7.49%
Canada	1992-1997	6	56.76	6.00	Yes	Americas	8.82%
Canada	1999-2008	10	56.76	6.80	Yes	Americas	8.03%
Cape Verde	1968-1975	8	15.11	3.63	No	Africa	12.94%
Cape Verde	1980-1985	6	15.11	11.50	No	Africa	17.40%
Caymen Islands	1986-1995	10	5.36	10.20	Yes	Caribbean	24.20%
Chile	1967-2008	42	-35.12	9.29	Yes	Americas	7.83%
China-Hong Kong	1973-1977	5	22.30	10.00	Yes	Asia	14.66%
China-Hong Kong	1979-2009	31	22.30	10.00	Yes	Asia	14.85%
China-Macao	1971-1975	5	22.17	9.60	Yes	Asia	16.52%
China-Macao	1984-1989	6	22.17	9.83	Yes	Asia	17.67%
China-Macao	1991-2010	20	22.17	9.70	Yes	Asia	16.06%
Cook Islands	1983-1988	6	-21.20	6.50	No	Asia	19.36%
Costa Rica	1987-1991	5	9.92	10.40	Yes	Americas	9.59%
Costa Rica	2003-2010	8	9.92	9.88	Yes	Americas	10.90%
Croatia	1988-2004	17	45.32	8.18	No	Europe	7.36%
Cuba	1976-1988	13	22.03	10.00	Yes	Caribbean	16.68%
Cuba	1990-2009	20	22.03	10.20	Yes	Caribbean	19.93%
Cyprus	1973-2009	37	34.97	8.49	Yes	Asia	11.88%
Czech Republic	1991-2010	14	49.82	5.36	Yes	Europe	10.15%
Denmark	1972-2005	34	55.85	6.03	Yes	Europe	9.57%
Egypt	1972-1982	11	28.80	7.00	Yes	Africa	30.08%
Egypt	1987-1999	13	28.80	10.85	No	Africa	35.30%
Egypt	2003-2009	7	28.80	9.29	No	Africa	12.60%
El Salvador	1973-2007	35	13.72	10.46	Yes	Americas	12.48%
Estonia	1989-1997	9	58.96	4.89	Yes	Europe	12.05%
Estonia	1999-2005	6	58.96	5.67	Yes	Europe	8.67%
Estonia	2007-2011	5	58.96	6.40	Yes	Europe	9.82%
Faeroe Islands	1972-1987	16	62.09	7.25	No	Europe	11.90%

Country	Years	No. Years	Latitude	Mean peak month	Significant	Group	Amplitude
Finland	1972-1988	17	61.76	4.94	Yes	Europe	10.55%
Finland	1994-2004	14	61.76	5.93	Yes	Europe	7.86%
France	1974-1989	16	47.14	5.75	Yes	Europe	10.02%
France	1991-1997	7	47.14	7.00	Yes	Europe	8.69%
France	1999-2004	6	47.14	7.83	Yes	Europe	8.06%
French Guiana	1977-1986	10	5.09	10.10	No	Americas	13.00%
French Guiana	1997-2003	7	5.09	10.71	No	Americas	12.35%
French Polynesia	1985-1992	8	-17.53	4.63	Yes	Asia	9.81%
Germany	1991-1997	7	50.86	7.14	Yes	Europe	7.72%
Germany	2004-2010	7	50.86	8.00	Yes	Europe	9.30%
Gibraltar	1973-1988	16	36.14	7.50	No	Europe	14.75%
Gibraltar	2002-2008	7	36.14	10.00	No	Europe	18.51%
Greece	1974-1985	12	38.69	6.00	Yes	Europe	10.53%
Greece	1990-2001	12	38.69	7.67	Yes	Europe	11.05%
Greenland	1972-1987	16	67.10	7.63	No	Europe	12.57%
Greenland	1992-2010	19	67.10	6.95	No	Europe	11.90%
Guadeloupe	1975-1980	6	16.27	9.33	No	Caribbean	10.58%
Guadeloupe	1982-1986	5	16.27	11.00	Yes	Caribbean	13.27%
Guadeloupe	1997-2003	7	16.27	10.57	Yes	Caribbean	16.23%
Guam	1973-1982	10	13.45	10.10	No	Asia	8.43%
Guam	1988-1992	5	13.45	9.80	No	Asia	9.40%
Guatemala	1972-1979	8	14.72	7.38	No	Americas	7.12%
Guatemala	1981-1999	19	14.72	10.79	No	Americas	9.54%
Guernsey	1973-1979	7	49.48	2.71	No	Europe	12.37%
Guernsey	1992-2000	9	49.48	8.22	No	Europe	11.49%
Guyana	1967-1971	5	6.35	9.60	Yes	Americas	10.04%
Hungary	1973-1992	20	47.29	6.40	Yes	Europe	8.74%
Hungary	1994-2004	11	47.29	7.73	No	Europe	7.90%
Iceland	1972-1980	9	64.37	5.67	Yes	Europe	10.39%
Iceland	1982-2004	22	64.37	6.77	Yes	Europe	10.23%
Iran	1999-2004	6	33.68	2.83	No	Asia	7.95%
Ireland	1972-2004	33	53.11	5.94	Yes	Europe	8.33%
Isle of Man	1973-1988	16	54.19	7.38	No	Europe	12.52%
Israel	1973-1981	9	31.78	9.33	Yes	Asia	9.58%
Israel	1983-1988	6	31.78	9.00	Yes	Asia	9.60%
Israel	1990-2009	20	31.78	9.60	Yes	Asia	8.97%
Italy	1970-1985	15	42.87	3.20	Yes	Europe	10.01%
Italy	1988-2009	22	42.87	8.14	Yes	Europe	11.01%
Jamaica	1999-2007	9	18.13	10.78	Yes	Caribbean	18.60%
Japan	1972-1992	21	35.41	7.48	Yes	Asia	7.59%
Japan	1994-2010	17	35.41	8.24	Yes	Asia	7.01%
Jersey	1973-1989	17	49.22	6.59	No	Europe	11.64%
Kazakhstan	1987-2008	22	43.35	6.27	No	Asia	10.11%
Korea Republic	1996-2009	24	36.47	4.83	No	Asia	7.75%
Kuwait	1975-1987	13	29.33	10.23	No	Asia	9.06%
Kuwait	1991-2008	18	29.33	9.44	No	Asia	10.68%
Kyrgyzstan	1985-2004	20	41.76	4.85	No	Asia	11.06%
Kyrgyzstan	2005-2009	5	41.76	7.40	Yes	Asia	12.02%
Latvia	1989-2005	17	56.83	5.12	Yes	Europe	11.12%
Lebanon	2003-2010	8	33.93	8.88	No	Asia	11.44%
Libya	1972-1981	10	29.96	1.00	Yes	Africa	12.01%
Libya	1989-1996	8	29.96	7.00	No	Africa	10.04%
Liechtenstein	1978-1987	10	47.15	6.80	No	Europe	13.16%
Liechtenstein	2000-2005	6	47.15	5.83	No	Europe	18.31%
Lithuania	1987-2011	25	55.22	5.72	Yes	Europe	13.11%
Luxembourg	1973-1989	17	49.64	6.47	No	Europe	9.22%
Luxembourg	1998-2010	13	49.64	6.23	Yes	Europe	10.08%
Malaysia	1994-2008	15	4.19	7.67	No	Asia	8.71%
Maldives	1978-2009	32	4.17	7.31	No	Europe	13.36%
Moldova Republic	1987-1992	6	47.17	5.67	No	Europe	7.60%
Moldova Republic	1998-2010	13	47.17	8.62	No	Europe	8.86%
Malta	1973-1988	16	35.90	9.06	Yes	Europe	11.41%
Malta	1992-2004	13	35.90	9.85	No	Europe	9.17%
Martinique	1975-1992	18	14.67	10.94	Yes	Caribbean	15.60%
Martinique	1998-2003	6	14.67	11.00	Yes	Caribbean	18.29%
Mauritius	1994-2010	17	-20.16	5.76	Yes	Africa	11.34%
Mongolia	1994-2003	10	47.77	5.10	No	Asia	8.24%
Netherlands	1973-1988	16	52.07	6.06	Yes	Europe	7.46%
Netherlands	1990-2010	21	52.07	7.62	Yes	Europe	6.63%
New Caledonia	1970-1977	8	-21.50	5.63	Yes	Asia	11.36%
New Caledonia	1982-2007	26	-21.50	5.54	Yes	Asia	12.12%
New Zealand	1972-2009	39	-41.44	7.46	Yes	Asia	23.52%
Niue	1982-1987	6	-19.06	7.83	No	Asia	45.89%
Norway	1976-1987	12	61.13	5.00	Yes	Europe	11.51%
Norway	1995-2004	10	61.13	5.50	Yes	Europe	9.64%
Occ. Palestinian Territory	1997-2007	11	31.88	10.64	Yes	Asia	10.81%

Country	Years	No. Years	Latitude	Mean birth month	Significant	Group	Amplitude
Palau	1997-2003	7	7.35	7.29	No	Asia	16.08%
Panama	1973-1999	27	8.75	10.78	Yes	Americas	8.35%
Panama	2005-2009	5	8.75	10.00	Yes	Americas	10.60%
Phillipines	1997-2007	11	11.87	10.00	Yes	Asia	13.93%
Poland	1978-2005	28	51.71	5.43	Yes	Europe	9.95%
Portugal	1973-1993	21	39.75	6.67	No	Europe	8.42%
Portugal	1999-2009	11	39.75	8.64	Yes	Europe	9.11%
Puerto Rico	1967-1985	19	18.26	10.05	Yes	Caribbean	11.33%
Puerto Rico	1987-1992	6	18.26	10.00	Yes	Caribbean	12.49%
Puerto Rico	1996-2000	5	18.26	10.00	Yes	Caribbean	11.71%
Puerto Rico	2002-2008	7	18.26	10.00	Yes	Caribbean	11.12%
Qatar	1985-1990	6	25.30	9.50	No	Asia	11.93%
Qatar	1999-2009	11	25.30	10.18	No	Asia	9.78%
Reunion	1977-1986	10	-21.11	6.40	Yes	Africa	7.53%
Reunion	1998-2003	6	-21.11	4.33	No	Africa	6.77%
Romania	1986-1992	7	45.69	6.29	Yes	Europe	9.60%
Romania	1994-2010	16	45.69	6.25	Yes	Europe	10.66%
Saint Helena ex dep	1981-1986	6	-15.93	6.83	No	Africa	31.44%
Saint Lucia	1976-1986	11	13.90	10.82	Yes	Caribbean	15.27%
Saint Lucia	1994-2002	9	13.90	11.00	Yes	Caribbean	20.24%
Saint Vincent and the Grenadines	1992-2005	14	13.20	11.07	Yes	Caribbean	23.24%
San Marino	1973-1978	6	43.94	7.33	No	Europe	21.85%
San Marino	1984-1989	6	43.94	9.50	No	Europe	29.63%
San Marino	2000-2004	5	43.94	7.60	No	Europe	21.12%
Sao Tome and Princepe	1967-1971	5	0.32	4.20	No	Africa	13.27%
Seychelles	1973-1993	21	-4.63	6.24	Yes	Africa	14.81%
Seychelles	1995-2010	16	-4.63	5.94	Yes	Africa	18.63%
Singapore	1973-2009	36	1.37	9.36	Yes	Asia	12.77%
Slovakia	1988-1995	8	48.66	5.75	Yes	Europe	10.10%
Slovakia	1998-2002	5	48.66	6.20	Yes	Europe	10.16%
Slovenia	1988-1996	9	46.17	6.67	No	Europe	7.17%
Slovenia	1998-2005	8	46.17	7.38	Yes	Europe	7.97%
Spain	1970-1985	16	39.72	6.38	Yes	Europe	8.40%
Spain	1991-2005	15	39.72	7.87	No	Europe	6.53%
Sri Lanka	1973-1986	14	7.57	9.14	No	Asia	7.64%
Sri Lanka	2005-2010	6	7.57	10.00	Yes	Asia	8.98%
Suriname	1989-2009	21	5.06	11.05	Yes	Americas	15.05%
Sweden	1973-1990	18	58.91	4.56	Yes	Europe	15.25%
Sweden	1992-2002	11	58.91	4.91	Yes	Europe	13.90%
Sweden	2004-2010	7	58.91	5.71	Yes	Europe	11.19%
Switzerland	1973-1982	10	47.03	5.00	Yes	Europe	10.33%
Switzerland	1984-1990	7	47.03	5.86	Yes	Europe	6.26%
Switzerland	1998-2002	5	47.03	6.80	No	Europe	5.78%
Tajikstan	1989-1994	6	38.70	4.00	Yes	Asia	23.24%
Macedonia	1989-1993	5	41.74	8.20	No	Europe	9.54%
Macedonia	1999-2010	12	41.74	7.83	Yes	Europe	10.20%
Tonga	1993-2000	8	-19.70	4.25	Yes	Asia	16.00%
Trinidad and Tobago	1972-1995	24	10.55	10.83	Yes	Caribbean	14.04%
Tunisia	1971-1976	6	35.42	2.83	Yes	Africa	16.04%
Tunisia	1978-1982	5	35.42	4.00	Yes	Africa	13.83%
Tunisia	1985-1995	11	35.42	5.18	No	Africa	13.40%
Tunisia	2001-2007	7	35.42	7.00	Yes	Africa	16.75%
Turks and Caicos Islands	1997-2005	9	21.51	9.56	No	Caribbean	25.43%
Ukraine	1980-1986	7	48.81	6.00	Yes	Europe	9.52%
Ukraine	1989-1996	8	48.81	5.75	Yes	Europe	9.77%
Ukraine	2003-2010	8	48.81	8.25	Yes	Europe	10.28%
UK + NI	1982-1988	7	52.75	6.71	Yes	Europe	6.85%
UK + NI	1990-2006	15	52.75	7.47	Yes	Europe	6.61%
USA	1969-1975	7	40.42	8.86	Yes	Americas	7.21%
USA	1978-2006	29	40.42	8.07	Yes	Americas	7.95%
USVI	1969-1973	5	18.33	10.80	Yes	Caribbean	19.68%
USVI	1980-1997	18	18.33	10.61	Yes	Caribbean	16.64%
Uruguay	1980-1988	9	-33.00	8.33	No	Americas	5.55%
Uzbekistan	1993-1997	5	40.68	5.80	No	Asia	8.36%
Venezuela	1972-2001	30	9.39	9.40	Yes	Americas	9.41%
Wallis and Futuna Islands	1973-1978	6	-13.30	4.00	No	Asia	10.72%