$$\frac{dS_t}{dt} = -\beta_t S_t \frac{I_t}{N}$$
$$\frac{dE_t}{dt} = \beta_t S_t \frac{I_t}{N} - \alpha E_t$$
$$\frac{dI_t}{dt} = \alpha E_t - \gamma I_t$$
$$\frac{dR_t}{dt} = \gamma I_t$$
$$\frac{dx_t}{dt} = \sigma dB_t$$
$$\beta_t = e^{x_t}$$
$$y_t \sim LogNormal(\frac{\alpha E_t}{5}, $$

H1N1-BM MODEL

PARAMETER SETTINGS

Parameter Prior Settings (directly take what set in H1N1 papers):

k ~ truncated_gaussian(1.59, 0.02, lower = 0)
gamma ~ truncated_gaussian(1.08, 0.075, lower = 0)
sigma ~U(0,1)
tau ~U(0,1)

Parameter True Values (also used to simulate data):

k (1/alpha, alpha is rate k is period)=1.59
gamma_period (1/gamma_rate)=1.08
sigma= 0.4
tau= 0.8

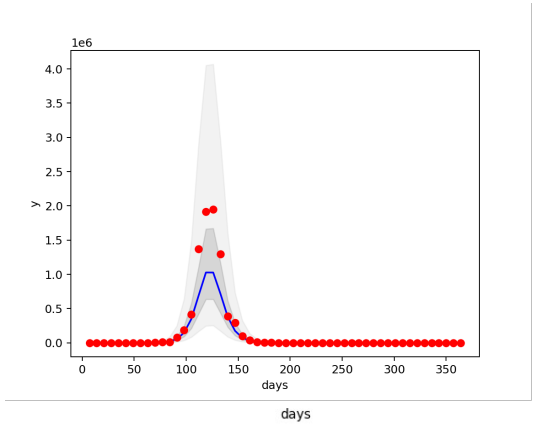
Parameter Proposal Settings (directly take what set in H1N1 papers):

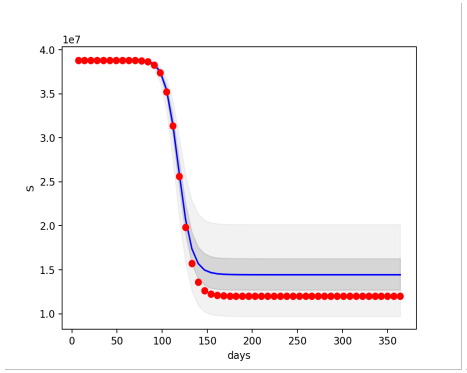
k ~ gaussian(k, 0.005)
gamma ~ gaussian(gamma, 0.01)
sigma ~ gaussian(sigma, 0.01)
tau ~ gaussian(tau,0.05)

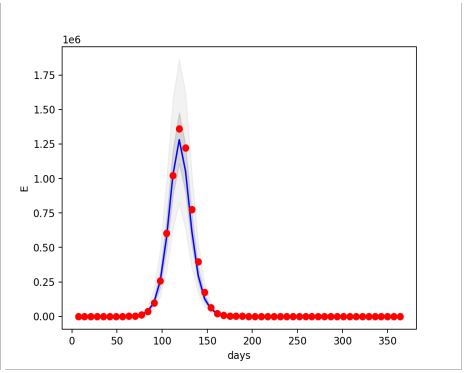
```
model_str <- "
model h1n1bm {
  obs y

  state S
  state E
  state I
  state R
  state x

  state Z

  input N
  param k
  param gamma
  param sigma // Noise driver
  param E0
  param I0
  param R0
  param x0
  param tau

  sub parameter {
    k ~ truncated_gaussian(1.59, 0.02, lower = 0) // k is the period here, not the rate, i.e. 1/k is the rate
    gamma ~ truncated_gaussian(1.08, 0.075, lower = 0) // gamma is the period, not the rate
    sigma ~ uniform(0,1)
    x0 ~ uniform(-5,2)
    I0 ~ uniform(-16, -9)
    E0 ~ uniform(-16, -9)
    R0 ~ truncated_gaussian(0.15, 0.15, lower = 0, upper = 1)
    tau ~ uniform(0, 1)
  }

  sub initial {
    S <- N
    R <- R0*S
    S <- S - R

    E <- exp(E0 + log(S))
    S <- S - E
    I <- exp(I0 + log(S))
    S <- S - I
    x <- x0
    Z <- 0
  }

  sub transition(delta = 1) {
  Z <- ((t_now) % 7 == 0 ? 0 : Z)
    noise e
    e ~ wiener()
    ode(alg = 'RK4(3)', h = 1.0, atoler = 1.0e-3, rtoler = 1.0e-8) {
      dx/dt = sigma*e
      dS/dt = -exp(x)*S*I/N
      dE/dt = exp(x)*S*I/N - E/k
      dI/dt = E/k-I/gamma
      dR/dt = I/gamma
      dZ/dt = E/k
    }
  }

  sub observation {
    y ~ log_normal(log(max(Z/5, 0)), tau)
  }

  sub proposal_parameter {
    k ~ gaussian(k, 0.005)
    sigma ~ gaussian(sigma, 0.01)
    gamma ~ gaussian(gamma, 0.01)
    x0 ~ gaussian(x0, 0.05)
    E0 ~ gaussian(E0, 0.05)
    I0 ~ gaussian(I0, 0.05)
    R0 ~ gaussian(R0, 0.05)
    tau ~ gaussian(tau, 0.05)
  }
}"
model <- bi_model(lines = stringi::stri_split_lines(model_str)[[1]])
bi_model <- libbi(model)
input_lst <- list(N = 52196381)
end_time <- max(y$time)
obs_lst <- list(y = y %>% dplyr::filter(time <= end_time))

bi <- sample(bi_model, end_time = end_time, input = input_lst, obs = obs_lst, nsamples = 2000, nparticles = minParticles, nthreads = ncores, proposal = 'prior',seed=123) %>%
  adapt_particles(min = minParticles, max = minParticles*500) %>%
  sample(nsamples =10000, thin = 1)

bi_lst <- bi_read(bi %>% sample_obs)
```

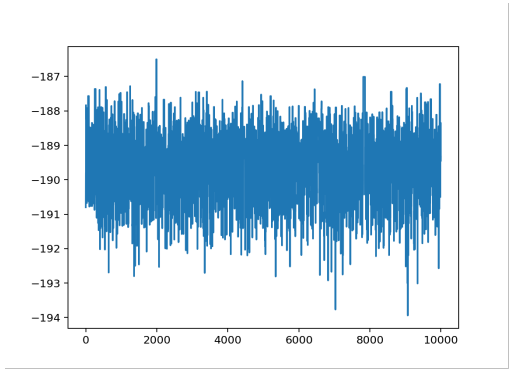
R code

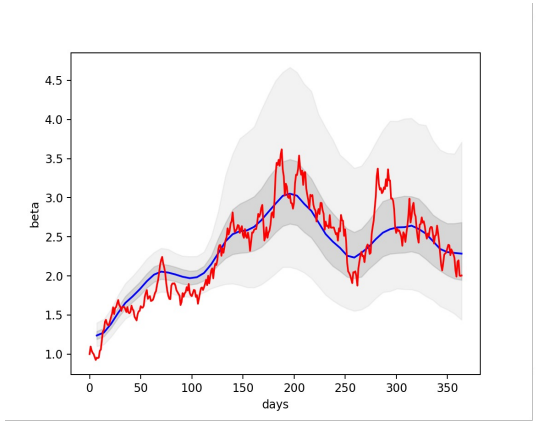
REDO 10.H1N1-BM:START POINT-FULL PARAMETER INFERENCE-REMOVE PROPOSAL ADAPTED TEST-PROPOSAL=PRIOR

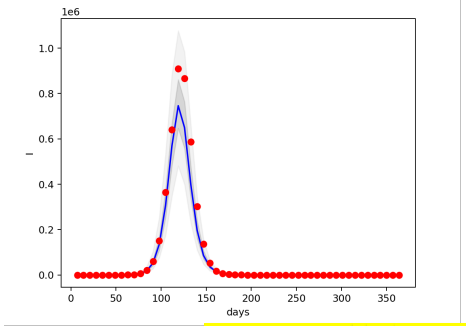


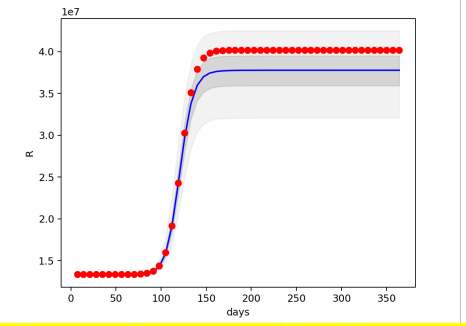




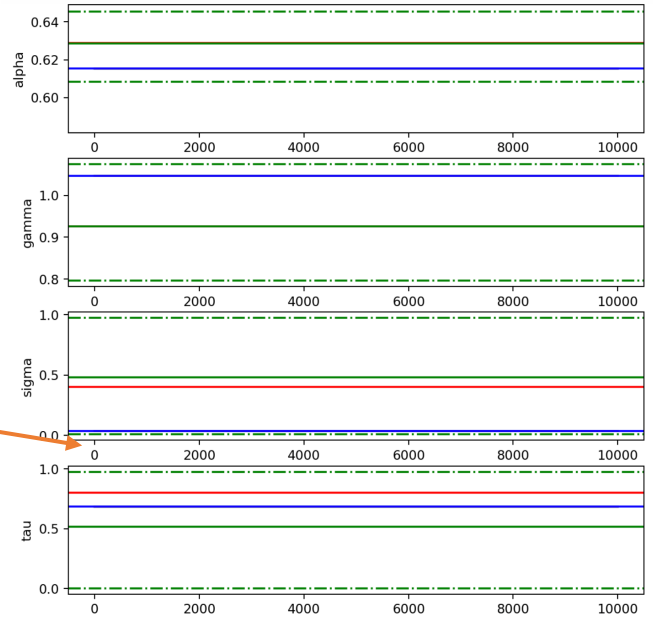








Issue: very tiny value of sigma



$$k = \frac{1}{\alpha} \sim TruncateGaussian(1.59, 0.02, lowerbound = 0)$$

$$\gamma_{period} = \frac{1}{\gamma} \sim TruncateGaussian(1.08, 0.075, lowerbound = 0)$$

$$\sigma \sim U(0,1)$$

$$\tau \sim U(0,1)$$

Prior

```
> bi <- sample(bi_model, end_time = end_time, input = input_lst, obs = obs_lst, nsamples = 2000, npar
+   adapt_particles(min = minParticles, max = minParticles*500) %>%
+   sample(nsamples =10000, thin = 1)
Tue Apr 25 11:46:07 2023 Adapting the number of particles
Tue Apr 25 11:57:49 2023 16 particles, loglikelihod variance: 3.08020793363653
Tue Apr 25 11:59:10 2023 32 particles, loglikelihod variance: 2.56597016900031
Tue Apr 25 12:00:29 2023 64 particles, loglikelihod variance: 1.76955352546487
Tue Apr 25 12:02:00 2023 128 particles, loglikelihod variance: 0.819822951538206
Tue Apr 25 12:02:00 2023 Choosing 128 particles.
>
> bi_lst <- bi_read(bi %>% sample_obs)
```

COVID-BM Model

$$\frac{dS_t}{dt} = -\beta_t(pE(A)_t + qI_t)\frac{S_t}{N}$$

$$\frac{dE(A)_t}{dt} = \beta_t(pE(A)_t + qI_t)\frac{S_t}{N} - (\alpha+\gamma)E(A)_t$$

$$\frac{dI_t}{dt} = \alpha E(A)_t - (\gamma + d)I_t$$

$$\frac{dR_t}{dt} = \gamma(E(A)_t + I_t) + I_t d$$

$$\frac{dx_t}{dt} = \sigma dB_t$$

$$\beta_t = e^{x_t}$$

$$y_t \sim LogNormal(\frac{\alpha E_t}{5}, \tau)$$

PARAMETER SETTINGS

Parameter Prior Settings (directly take what set in H1N1 papers):

k ~ truncated_gaussian(5, 0.01, lower = 0)
gamma ~ truncated_gaussian (5, 0.01, lower = 0)
sigma ~ truncated_gaussian(sqrt(0.004), 0.01, lower = 0)
tau ~U(0,1)

Parameter True Values (also used to simulate data):

k (1/alpha, alpha is rate k is period)=5
gamma_period (1/gamma_rate)=5
sigma= sqrt(0.004)
tau= 0.8

Parameter Proposal Settings (directly take what set in H1N1 papers):

k ~ truncated_gaussian(k, 0.001, lower=0)
gamma ~ truncated_gaussian(gamma, 0.001,lower=0)
sigma ~ truncated_gaussian(sigma, 0.00001, lower=0)
tau ~ gaussian(tau,0.05)

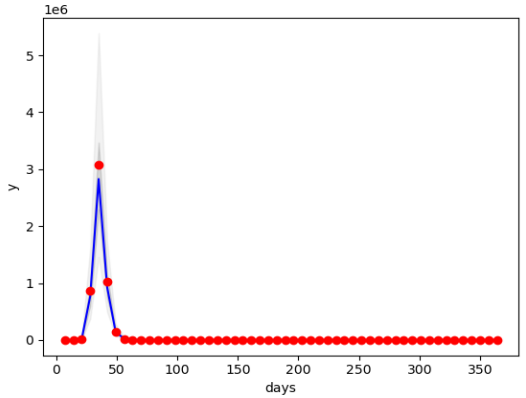
Parameter initial Settings:

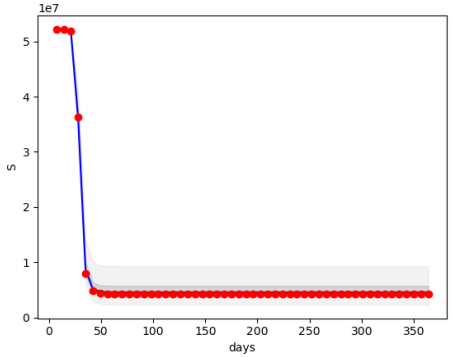
k =3 gamma =3 sigma=sqrt(0.003) tau=0.8

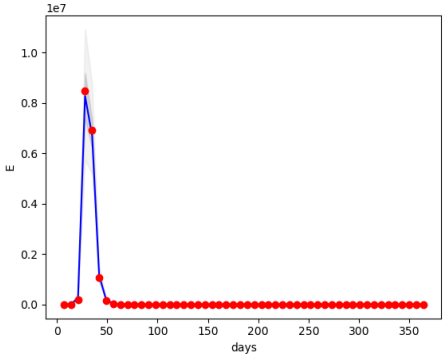
```
model_str <- "
model covidbm {
  obs y

  state S
  state E
  state I
  state R
  state x
  state Z

  input N

  param k
  param gamma
  param sigma
  param tau

  sub parameter {
    k ~ truncated_gaussian(5, 0.01, lower = 0)
    gamma ~ truncated_gaussian(5, 0.01, lower = 0) // gamma is the period, not the rate
    sigma ~ truncated_gaussian(sqrt(0.004), 0.001, lower = 0)
    tau ~ uniform(0, 1)
  }

  sub initial {
    S <- N-1
    E <- 1
    I <- 0
    R <- 0
    Z <- 0
  }

  sub transition(delta = 1) {
  Z <- ((t_now) % 7 == 0 ? 0 : Z)
    noise e
    e ~ wiener()
    ode(alg = 'RK4(3)', h = 1.0, atoler = 1.0e-3, rtoler = 1.0e-8) {
      dx/dt = sigma*e
      dS/dt = -exp(x)*S*(0.1*I+E)/N
      dE/dt = exp(x)*S*(0.1*I+E)/N - E*(1/k+1/gamma)
      dI/dt = E/k-I*(1/gamma+0.0087)
      dR/dt = (I+E)/gamma+0.0087*I
      dZ/dt = E/k
    }

  sub observation {
    y ~ log_normal(log(max(Z/5, 0)), tau)
  }

  sub proposal_parameter {
    k ~ truncated_gaussian(k, 0.001, lower = 0)
    gamma ~ truncated_gaussian(gamma, 0.001, lower = 0)
    sigma ~ truncated_gaussian(sigma, 0.001, lower = 0)
    tau ~ gaussian(tau, 0.05)
  }
}"
model <- bi_model(lines = stringi::stri_split_lines(model_str)[[1]])
bi_model <- libbi(model)
input_lst <- list(N = 52196381)
end_time <- max(y$time)
obs_lst <- list(y = y %>% dplyr::filter(time <= end_time))
init_list <- list(k=3,gamma=3,sigma=sqrt(0.003),tau=0.8)

bi <- sample(bi_model, end_time = end_time, input = input_lst, init=init_list, obs = obs_lst, nsamples = 1000, nparticles = minParticles, nthreads = ncores, proposal = 'model',seed=0123112)
  adapt_particles(min = minParticles, max = minParticles*500) %>%
  sample(nsamples = 10000, thin = 1)

bi_lst <- bi_read(bi %>% sample_obs)
```

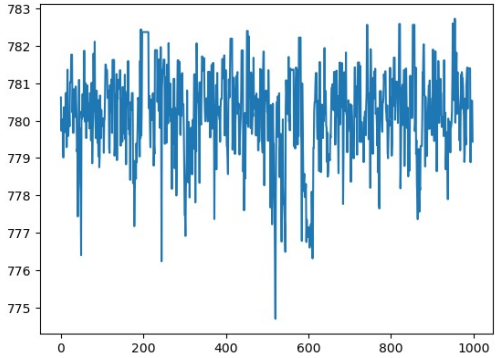
R code

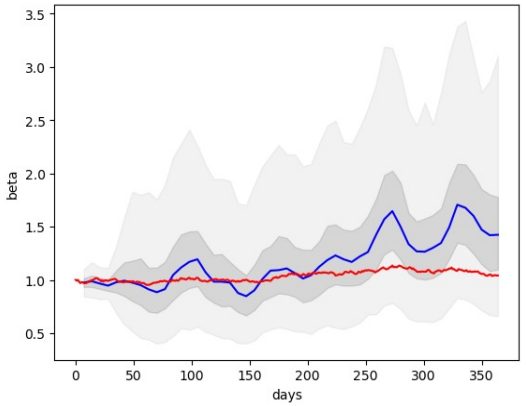
1-8.Covid-Bm: full parameter inference-sigma=sqrt(0.004)

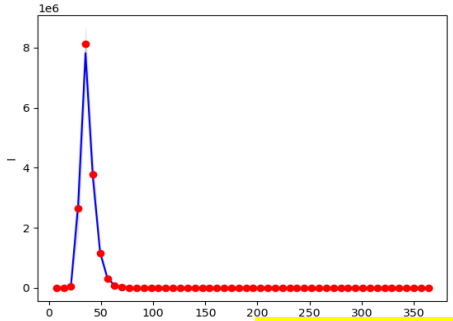


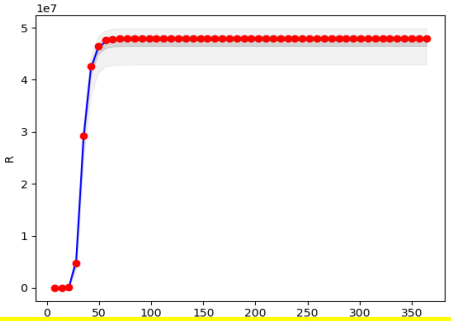


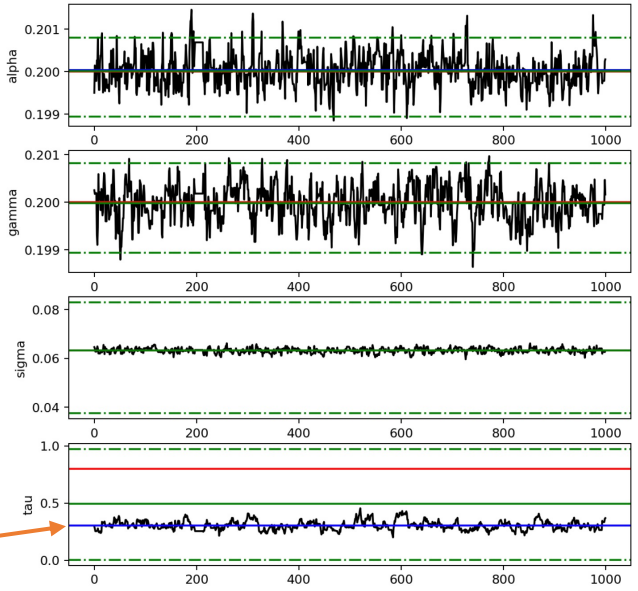












$$k = \frac{1}{\alpha} \sim TruncateGaussian(5, 0.01, lowerbound = 0)$$

$$\gamma_{period} = \frac{1}{\gamma} \sim TruncateGaussian(5, 0.01, lowerbound = 0)$$

$$\sigma \sim TruncateGaussian(\sqrt{0.004}, 0.001, lowerbound = 0)$$

$$\tau \sim U(0,1)$$

Prior

Issue: the posterior sample does not start from where we set the initial value to be so how to discard burn-in correctly in LibBi