options(scipen=999)

library(rstan)

library(loo)

library(R2OpenBUGS)

library(MCMCvis)

# Data

eas=c(0.147,0.247,0.158,0.157,0.263,0.233,0.191,0.173,0.233,0.182,0.142,0.188,0.225,0.143,0.225,

0.133,0.097,0.14,0.204,0.201,0.224,0.126,0.096,0.196,0.164,0.176,0.229,0.076,0.131,0.176,0.111,

0.084,0.234,0.151,0.255,0.219,0.137,0.214,0.219,0.165,0.088,0.192,0.186,0.164,0.235,0.078,0.197,

0.165,0.152,0.178,0.165,0.118,0.084,0.211,0.214,0.094,0.221,0.124,0.134,0.192,0.075,0.204,0.118,

0.225,0.211,0.265,0.219,0.104,0.141,0.133,0.16,0.099,0.14,0.115,0.225,0.081,0.152,0.157,0.123,

0.078,0.226)

nor=c(51.547,51.55,51.53,51.54,51.563,51.595,51.553,51.586,51.606,51.58,51.553,51.579,51.606,

51.54,51.606,51.537,51.541,51.574,51.574,51.543,51.562,51.539,51.543,51.544,51.602,51.561,

51.561,51.541,51.553,51.561,51.538,51.533,51.592,51.561,51.557,51.567,51.585,51.522,51.556,

51.583,51.534,51.533,51.532,51.542,51.559,51.542,51.519,51.6,51.535,51.565,51.6,51.546,51.539,

51.6,51.527,51.535,51.584,51.561,51.561,51.573,51.55,51.547,51.546,51.606,51.6,51.569,51.567,

51.528,51.559,51.537,51.545,51.539,51.574,51.551,51.606,51.531,51.535,51.533,51.545,51.535,

51.593)

easnew=c(0.131,0.169,0.14,0.244,0.137,0.22,0.255,0.199,0.248,0.192,0.197)

nornew=c(51.551,51.59,51.574,51.551,51.585,51.556,51.554,51.562,51.558,51.533,51.519)

eas=eas+runif(81,-sd(eas)/10,sd(eas)/10)

nor=nor+runif(81,-sd(nor)/10,sd(nor)/10)

easting=c(eas,easnew)

northing=c(nor,nornew)

df <- data.frame(easting=easting,northing = northing)

dist=as.matrix(dist(df))

N1=81

N2=11

**#**

**# rstan estimation, exponential covariance**

**#**

D=list(dist=dist,

y1=c(90,81,78,135,191,177,292,291,244,217,96,176,175,132,133,194,109,122,122,260,55,146,35,

49,217,70,52,40,118,46,40,58,40,157,78,92,53,84,106,52,89,68,23,78,62,43,77,160,92,57,23,94,44,

81,103,74,29,509,24,43,27,71,56,43,69,74,51,140,89,134,58,173,20,63,55,7,66,27,64,32,64),

n1=c(4681,4581,3417,4997,11250,12625,15793,13179,6788,10714,5730,15307,7450,4705,6815,7809,9745,6460,9745,10538,4134,3994,2581,6993,11174,4914,3182,2955,5039,2662,2203,4924,3447,8561,2545,3752,3187,4694,4457,2730,3904,2217,1846,2589,3515,4014,3635,4924,2859,4177,2070,3523,2474,2781,4872,4185,2246,7260,2555,2738,1785,2878,2520,1921,2563,4170,4616,4492,4482,4034,3608,5605,2667,2358,3884,1417,4306,2054,5014,4667,1671),

N1=N1,N2=N2,

x=c(37.007,7.008,31.175,38.052,6.329,15.527,14.452,17.15,32.018,22.037,35.439,15.258,32.647,

37.792,33.071,36.315,27.483,24.813,12.103,14.643,23.207,36.028,23.009,18.155,21.263,25.886,

10.591,34.428,33.21,23.011,37.45,36.638,17.722,37.342,7.816,11.236,38.821,20.077,12.066,

18.283,27.697,19.116,21.889,31.949,10.612,32.443,24.057,21.795,34.13259,22.812,21.081,35.506,

29.711,31.508,17.355,32.618,12.083,34.398,30.714,17.567,30.613,13.08,36.537,33.156,31.752,

7.728,10.968,37.436,34.651,36.737,31.707,33.822,25.301,34.158,32.613,37.323,36.142,32.811,

36.868,34.454,20.702,35.448,18.56,24.957,6.621,39.523,12.58,7.299,18.439,8.559,18.792,21.369))

disprev.stan <- "

data {

int<lower=1> N1; //number of data points

int y1[N1]; // binomial responses

int n1[N1]; // binomial denominators

int<lower=1> N2; // number of new points

matrix[N1+N2,N1+N2] dist; //distances between points

real x[N1+N2]; // deprivation scores

}

transformed data {

int<lower=1> N;

N = N1 + N2;

}

parameters{

vector[N1] eta1;

vector[N2] eta2;

real beta[2];

real <lower=0> sigma\_sq;

real <lower=0> phi;

}

transformed parameters {

vector[N1+N2] mu;

for(i in 1:N) mu[i] = beta[1]+beta[2]\*x[i];

}

model {

vector[N] logit\_p;

matrix[N,N] Sigma;

matrix[N,N] L;

for(i in 1:N1) logit\_p[i] = eta1[i];

for(i in 1:N2) logit\_p[N1+i] = eta2[i];

for(i in 1:(N-1)){ for(j in (i+1):N){

Sigma[i,j] = exp(-phi\*dist[i,j]);

Sigma[j,i] = Sigma[i,j];

}

}

for(i in 1:N) Sigma[i,i] = sigma\_sq;

L = cholesky\_decompose(Sigma);

sigma\_sq ~ normal(0, 5);

phi ~ normal(0, 5);

logit\_p ~ multi\_normal\_cholesky(mu,L);

beta ~ normal(0,5);

y1 ~ binomial\_logit(n1,eta1);

}

generated quantities {

vector[N2] p\_pred;

vector[N1] log\_lik;

for (i in 1:N2) p\_pred[i] = inv\_logit(eta2[i]);

for (i in 1:N1) {log\_lik[i] =binomial\_logit\_lpmf( y1[i]| n1[i] , eta1[i] );}

}

"

**# Estimation**

sm <- stan\_model(model\_code=disprev.stan)

fit <- sampling(sm,data =D,iter = 1250,warmup=250,chains = 2,seed= 12345)

**# Fit**

LL1 <- as.matrix(fit,pars="log\_lik")

loo(LL1)

**# predictions at new locations**

psamps = as.matrix(fit, pars = "p\_pred")

p\_pred\_mean1=apply(psamps,2,mean)

**#**

**# R2OpenBUGS estimation, powered exponential**

**#**

D=list(eas=eas,nor=nor,easnew=easnew,nornew=nornew,

y1=c(90,81,78,135,191,177,292,291,244,217,96,176,175,132,133,194,109,122,122,260,55,146,35,

49,217,70,52,40,118,46,40,58,40,157,78,92,53,84,106,52,89,68,23,78,62,43,77,160,92,57,23,94,44,

81,103,74,29,509,24,43,27,71,56,43,69,74,51,140,89,134,58,173,20,63,55,7,66,27,64,32,64),

n1=c(4681,4581,3417,4997,11250,12625,15793,13179,6788,10714,5730,15307,7450,4705,6815,

7809,9745,6460,9745,10538,4134,3994,2581,6993,11174,4914,3182,2955,5039,2662,2203,4924,

3447,8561,2545,3752,3187,4694,4457,2730,3904,2217,1846,2589,3515,4014,3635,4924,2859,4177,2070,3523,2474,2781,4872,4185,2246,7260,2555,2738,1785,2878,2520,1921,2563,4170,4616,4492,4482,4034,3608,5605,2667,2358,3884,1417,4306,2054,5014,4667,1671),

N1=81,N2=11,

x=c(37.007,7.008,31.175,38.052,6.329,15.527,14.452,17.15,32.018,22.037,35.439,15.258,32.647,

37.792,33.071,36.315,27.483,24.813,12.103,14.643,23.207,36.028,23.009,18.155,21.263,25.886,

10.591,34.428,33.21,23.011,37.45,36.638,17.722,37.342,7.816,11.236,38.821,20.077,12.066,

18.283,27.697,19.116,21.889,31.949,10.612,32.443,24.057,21.795,34.13259,22.812,21.081,35.506,

29.711,31.508,17.355,32.618,12.083,34.398,30.714,17.567,30.613,13.08,36.537,33.156,31.752,

7.728,10.968,37.436,34.651,36.737,31.707,33.822,25.301,34.158,32.613,37.323,36.142,32.811,

36.868,34.454,20.702),

xnew=c(35.448,18.56,24.957,6.621,39.523,12.58,7.299,18.439,8.559,18.792,21.369))

model1 <- function() { for (i in 1 : N1) {

nought[i] <- 0

y1[i] ~ dbin(p1[i],n1[i])

d1[i] <- n1[i]-y1[i]

LL[i] <- logfact(n1[i])-logfact(y1[i])-logfact(d1[i])+y1[i]\*log(p1[i])+d1[i]\*log(1-p1[i])

logit(p1[i]) <- beta[1]+beta[2]\*(x[i]-25.3)+s[i]}

# powered exponential prior

s[1:N1] ~ spatial.exp(nought[],eas[],nor[],tau.s,phi.inv,kappa)

# prediction at new locations

for(i in 1:N2) { snew[i] ~ spatial.unipred(0,easnew[i], nornew[i],s[])

logit(pnew[i]) <- beta[1]+beta[2]\*(xnew[i]-25.3)+snew[i]}

# priors

for (j in 1:2) {beta[j] ~ dnorm(0,0.01)}

phi.inv ~ dunif(0.1,5)

phi <- 1/phi.inv

kappa ~ dunif(0,2)

# Spatial Variance

sigma2.s <- 1/tau.s

tau.s ~ dgamma(1,0.001) }

**# Estimation**

init1=list(beta=c(-4.2,0.01),phi.inv=1,kappa=0.1,tau.s=1,s=rep(0,N1),snew=rep(0,N2))

init2=list(beta=c(-4.1,0.009),phi.inv=1.5,kappa=0.2,tau.s=2,s=rep(0,N1),snew=rep(0,N2))

inits=list(init1,init2)

pars <- c("phi","kappa","beta","pnew","LL","snew","sigma2.s")

n.iters=3000; n.burnin=250; n.chains=2

R1 = bugs(D,inits,pars,n.iters,model1,n.chains,n.burnin,debug=T,codaPkg=T,bugs.seed=10)

MCMCsummary(read.bugs(R1),digits=3)

samps <- do.call(rbind.data.frame, read.bugs(R1))

**# Fit**

LL2=as.matrix(samps[,1:N1])

loo(LL2)

**# predictions at new locations**

psamps=as.matrix(samps[,87:97])

p\_pred\_mean2=apply(psamps,2,mean)

cor(p\_pred\_mean1, p\_pred\_mean2)