Basic CAR Model

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6/30/2021

```
library(here)
```

```
## here() starts at /Users/Alvin/Documents/NCSU_Fall_2021/NIH_SIP/flood-risk-health-effects
```

```
library(coda)
library(CARBayes)
```

```
## Loading required package: MASS
```

```
## Loading required package: Rcpp
```

```
## Registered S3 method overwritten by 'GGally':
##   method from
##   +.gg   ggplot2
```

CAR model results

Inference is based on 3 markov chains, each of which has been run for 100000 samples, the first 10000 of which has been removed for burn-in. The remaining 90000 samples are thinned by 5, resulting in 18000 * 3 = 54000 samples for inference across the 3 Markov chains.

```
load(here("modeling_files/model_3chains_var_exclude.RData"))
```

Output for the first chain is shown below.

```
chain1
```

```
##
## #################
## #### Model fitted
## #################
## Likelihood model - Gaussian (identity link function)
## Random effects model - Leroux CAR
## Regression equation - Y ~ X
## <environment: 0x7fe234232138>
## Number of missing observations - 0
##
## ############
## #### Results
## ############
## Posterior quantities and DIC
##
##                           Median    2.5%   97.5% n.effective Geweke.diag
## (Intercept)             77.7452 77.7251 77.7653     18689.9         0.3
```

```
## Xpct_fs_risk_2020_5     -0.1016 -0.1906 -0.0124     11053.9         1.9
## Xpct_floodfactor2        0.0127 -0.0324  0.0579     12617.9         0.4
## Xpct_floodfactor3       -0.0171 -0.0615  0.0276     13178.6        -0.3
## Xpct_floodfactor4        0.0376 -0.0125  0.0872     10787.8         0.7
## Xpct_floodfactor5       -0.0152 -0.0768  0.0456     10673.1         0.4
## Xpct_floodfactor6        0.0120 -0.0513  0.0765     12809.2        -0.3
## Xpct_floodfactor7       -0.0247 -0.0751  0.0250     12246.9         0.6
## Xpct_floodfactor8       -0.0079 -0.0515  0.0355     14942.8         0.0
## Xpct_floodfactor9        0.0737  0.0025  0.1453     10981.6        -0.1
## Xavg_risk_fsf_2020_100   0.0846  0.0060  0.1633     10564.3        -0.3
## Xavg_risk_score_sfha     0.0073 -0.0431  0.0567     12371.4        -1.4
## Xavg_risk_score_no_sfha -0.0003 -0.0867  0.0850     10613.7        -1.2
## XEP_POV                 -0.2392 -0.3080 -0.1722     12050.9         1.8
## XEP_UNEMP               -0.0360 -0.0847  0.0115     12271.3        -1.7
## XEP_PCI                  0.1736  0.1011  0.2465     10914.6         0.3
## XEP_NOHSDP              -0.0252 -0.1054  0.0554      9205.2        -2.7
## XEP_AGE65                0.1710  0.1049  0.2353     10026.9        -1.1
## XEP_AGE17               -0.1697 -0.2372 -0.1012     10679.7        -0.4
## XEP_DISABL              -0.2602 -0.3240 -0.1965     10898.1        -0.6
## XEP_SNGPNT              -0.1309 -0.1797 -0.0823     14673.0         0.1
## XEP_MINRTY              -0.3042 -0.3881 -0.2211      5256.1        -0.1
## XEP_LIMENG               0.3428  0.2775  0.4087      9175.7         0.6
## XEP_MUNIT                0.1322  0.0692  0.1956      9975.9        -1.6
## XEP_MOBILE              -0.0815 -0.1412 -0.0217      8683.6         0.6
## XEP_CROWD               -0.0163 -0.0661  0.0330     10094.9        -0.3
## XEP_NOVEH               -0.1388 -0.1922 -0.0850     11882.0         0.9
## XEP_GROUPQ               0.0742  0.0296  0.1183     12649.3         0.9
## XEP_UNINSUR             -0.0187 -0.0777  0.0382      7656.1        -0.8
## Xco                     -0.1166 -0.1840 -0.0478      4301.1        -2.4
## Xno2                    -0.0166 -0.1124  0.0789      4530.7         0.6
## Xo3                     -0.0054 -0.1331  0.1184      1053.2         0.2
## Xpm10                    0.1308  0.0517  0.2107      3583.4        -0.3
## Xpm25                   -0.2496 -0.3638 -0.1337      1548.8        -0.3
## Xso2                    -0.0781 -0.1285 -0.0287      6567.2        -1.3
## Xtotal_mean             -0.9351 -1.0075 -0.8626      7598.8         1.0
## nu2                      0.3328  0.2732  0.3916      1848.1        -2.2
## tau2                     1.6948  1.4109  2.0184      1856.7         2.3
## rho                      0.9922  0.9749  0.9991      8336.4        -2.8
##
## DIC =  6952.404       p.d =  1562.954       LMPL =  -3782.28
```

The smallest effective sample size is 935.8, for ozone (o3).

```
chain1$accept
```

```
##      beta       phi       nu2      tau2       rho
## 100.00000 100.00000 100.00000 100.00000  46.92342
```

It appears that beta, phi, nu2, and tau2 probably have Gibbs steps, whereas rho has a Metropolis-Hastings step. In any case, the acceptance probabilities are acceptable.

Model Diagnostics

Beta samples

```r
beta_samples <- mcmc.list(chain1$samples$beta, chain2$samples$beta,
                          chain3$samples$beta)
```

```r
plot(beta_samples)
```

```r
gelman.diag(beta_samples)
```

```
## Potential scale reduction factors:
##
##       Point est. Upper C.I.
##  [1,]          1       1.00
##  [2,]          1       1.00
##  [3,]          1       1.00
##  [4,]          1       1.00
##  [5,]          1       1.00
##  [6,]          1       1.00
##  [7,]          1       1.00
##  [8,]          1       1.00
##  [9,]          1       1.00
## [10,]          1       1.00
## [11,]          1       1.00
## [12,]          1       1.00
## [13,]          1       1.00
## [14,]          1       1.00
## [15,]          1       1.00
## [16,]          1       1.00
## [17,]          1       1.00
## [18,]          1       1.00
## [19,]          1       1.00
## [20,]          1       1.00
## [21,]          1       1.00
## [22,]          1       1.00
## [23,]          1       1.00
## [24,]          1       1.00
## [25,]          1       1.00
## [26,]          1       1.00
## [27,]          1       1.00
## [28,]          1       1.00
## [29,]          1       1.00
## [30,]          1       1.00
## [31,]          1       1.00
## [32,]          1       1.01
## [33,]          1       1.00
## [34,]          1       1.00
## [35,]          1       1.00
## [36,]          1       1.00
##
## Multivariate psrf
##
## 1.01
```

Examining tau2, nu2, rho

```
tau2_samples <- mcmc.list(chain1$samples$tau2, chain2$samples$tau2,
                          chain3$samples$tau2)

nu2_samples <- mcmc.list(chain1$samples$nu2, chain2$samples$nu2,
                          chain3$samples$nu2)

rho_samples <- mcmc.list(chain1$samples$rho, chain2$samples$rho,
                          chain3$samples$rho)
```

```
plot(tau2_samples)

plot(nu2_samples)

plot(rho_samples)
```

```
gelman.diag(tau2_samples)
```

```
## Potential scale reduction factors:
##
##      Point est. Upper C.I.
## [1,]          1          1
```

```
gelman.diag(nu2_samples)
```

```
## Potential scale reduction factors:
##
##      Point est. Upper C.I.
## [1,]          1          1
```

```
gelman.diag(rho_samples)
```

```
## Potential scale reduction factors:
##
##      Point est. Upper C.I.
## [1,]          1          1
```

Examining a sample of the 3108 phi parameters

```
phi_samples <- mcmc.list(chain1$samples$phi, chain2$samples$phi, chain3$samples$phi)
```

```
set.seed(1157, kind = "Mersenne-Twister", normal.kind = "Inversion", sample.kind = "Rejection")

phi_subset_idx <- sample(1:3108, size = 10)

phi_samples_subset <- phi_samples[, phi_subset_idx]
```

```
plot(phi_samples_subset)
```

```
gelman.diag(phi_samples_subset)
```

```
## Potential scale reduction factors:
##
##       Point est. Upper C.I.
```

```
##  [1,]          1          1
##  [2,]          1          1
##  [3,]          1          1
##  [4,]          1          1
##  [5,]          1          1
##  [6,]          1          1
##  [7,]          1          1
##  [8,]          1          1
##  [9,]          1          1
## [10,]          1          1
##
## Multivariate psrf
##
## 1
```

Inference

```r
beta_samples_matrix <- rbind(chain1$samples$beta, chain2$samples$beta, chain3$samples$beta)

colnames(beta_samples_matrix) <- colnames(chain1$X)
```

```r
(beta_inference <- round(t(apply(beta_samples_matrix, 2, quantile, c(0.5, 0.025, 0.975))),5))
```

```
##                              50%     2.5%    97.5%
## (Intercept)             77.74530 77.72501 77.76544
## Xpct_fs_risk_2020_5     -0.10169 -0.19068 -0.01293
## Xpct_floodfactor2        0.01273 -0.03227  0.05773
## Xpct_floodfactor3       -0.01700 -0.06174  0.02753
## Xpct_floodfactor4        0.03760 -0.01247  0.08752
## Xpct_floodfactor5       -0.01543 -0.07681  0.04558
## Xpct_floodfactor6        0.01202 -0.05132  0.07611
## Xpct_floodfactor7       -0.02478 -0.07474  0.02570
## Xpct_floodfactor8       -0.00783 -0.05098  0.03563
## Xpct_floodfactor9        0.07366  0.00290  0.14517
## Xavg_risk_fsf_2020_100   0.08453  0.00568  0.16396
## Xavg_risk_score_sfha     0.00722 -0.04282  0.05702
## Xavg_risk_score_no_sfha -0.00041 -0.08648  0.08444
## XEP_POV                 -0.23905 -0.30693 -0.17180
## XEP_UNEMP               -0.03622 -0.08435  0.01189
## XEP_PCI                  0.17396  0.10115  0.24697
## XEP_NOHSDP              -0.02542 -0.10635  0.05583
## XEP_AGE65                0.17078  0.10560  0.23442
## XEP_AGE17               -0.16930 -0.23649 -0.10168
## XEP_DISABL              -0.26018 -0.32312 -0.19699
## XEP_SNGPNT              -0.13114 -0.18006 -0.08239
## XEP_MINRTY              -0.30407 -0.38753 -0.22019
## XEP_LIMENG               0.34244  0.27746  0.40798
## XEP_MUNIT                0.13257  0.07005  0.19535
## XEP_MOBILE              -0.08118 -0.14171 -0.02074
## XEP_CROWD               -0.01665 -0.06598  0.03210
## XEP_NOVEH               -0.13876 -0.19236 -0.08552
## XEP_GROUPQ               0.07403  0.02951  0.11825
## XEP_UNINSUR             -0.01885 -0.07766  0.03871
```

```
## Xco                         -0.11598 -0.18327 -0.04722
## Xno2                        -0.01786 -0.11408  0.07894
## Xo3                         -0.00905 -0.13604  0.11692
## Xpm10                        0.13050  0.05043  0.21101
## Xpm25                       -0.24814 -0.36539 -0.13225
## Xso2                        -0.07772 -0.12782 -0.02721
## Xtotal_mean                 -0.93518 -1.00684 -0.86332
```

List of significant beta coefficients:

```
colnames(beta_samples_matrix)[sign(beta_inference[, 2]) == sign(beta_inference[, 3])]
```

```
##  [1] "(Intercept)"            "Xpct_fs_risk_2020_5"    "Xpct_floodfactor9"
##  [4] "Xavg_risk_fsf_2020_100" "XEP_POV"                "XEP_PCI"
##  [7] "XEP_AGE65"              "XEP_AGE17"              "XEP_DISABL"
## [10] "XEP_SNGPNT"             "XEP_MINRTY"             "XEP_LIMENG"
## [13] "XEP_MUNIT"              "XEP_MOBILE"             "XEP_NOVEH"
## [16] "XEP_GROUPQ"             "Xco"                    "Xpm10"
## [19] "Xpm25"                  "Xso2"                   "Xtotal_mean"
```