COVID-19-Spain-Analysis

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This notebook reports our initial analysis of COVID-19 incidence in Spain and the climatic correlates of incidence. The data have been organized in a package for ease of access and distribution. The name of the package is `covid19env` and if necessary can be installed from the GitHub repository.

Preliminaries

Load packages:

```
library(covid19env)
library(ggthemes)
library(gridExtra)
library(lubridate)
library(sf)
library(spdep)
library(spsur)
library(tidyverse)
library(units)
#library(spatialreg)
#library(systemfit)
#library(plm)
#library(splm)
```

Load data from package `covid19env`

```
data("covid19_spain")
```

Summarize the data:

```
covid19_spain %>%
  select(-geometry) %>%
  summary()
```

```
##              province                      CCAA         ID_INE
##  Albacete        : 22   Castilla y Leon     :198   Min.   : 1.0
##  Alicante/Alacant: 22   Andalucia           :176   1st Qu.:13.0
##  Almeria         : 22   Castilla - La Mancha:110   Median :25.5
##  Araba/alava     : 22   CataluÃ±a           : 88   Mean   :25.5
##  Asturias        : 22   Galicia             : 88   3rd Qu.:38.0
##  Avila           : 22   Aragon              : 66   Max.   :50.0
##  (Other)         :968   (Other)             :374
##       Date                Cases           Incidence          Population
##  Min.   :2020-03-14   Min.   :    1.0   Min.   :  0.4536   Min.   :  88636
##  1st Qu.:2020-03-19   1st Qu.:  126.0   1st Qu.: 20.0996   1st Qu.: 331549
##  Median :2020-03-24   Median :  378.5   Median : 62.1017   Median : 684202
##  Mean   :2020-03-24   Mean   : 1073.2   Mean   :109.3028   Mean   : 974257
```

```
##  3rd Qu.:2020-03-30   3rd Qu.:  957.2   3rd Qu.:148.8700   3rd Qu.:1149460
##  Max.   :2020-04-04   Max.   :36249.0   Max.   :867.5933   Max.   :6663394
##
##      Older          Median_Age     Male2Female         GDPpc          Transit
##  Min.   :15.16   Min.   :40.19   Min.   : 91.59   Min.   :16666   Min.   :0.0
##  1st Qu.:18.02   1st Qu.:42.35   1st Qu.: 95.43   1st Qu.:18813   1st Qu.:0.0
##  Median :19.93   Median :43.70   Median : 98.06   Median :20870   Median :0.0
##  Mean   :21.03   Mean   :44.55   Mean   : 97.83   Mean   :22506   Mean   :0.1
##  3rd Qu.:23.07   3rd Qu.:46.01   3rd Qu.:100.08   3rd Qu.:25901   3rd Qu.:0.0
##  Max.   :31.36   Max.   :50.68   Max.   :103.01   Max.   :36001   Max.   :1.0
##
##       Area              Altitude          Coast      Meteo_Station
##  Min.   :1.979e+09   Min.   :   5.0   Min.   :0.00   0016A  : 22
##  1st Qu.:6.637e+09   1st Qu.:  24.0   1st Qu.:0.00   0076   : 22
##  Median :1.001e+10   Median : 215.5   Median :0.00   0367   : 22
##  Mean   :1.012e+10   Mean   : 369.0   Mean   :0.42   1024E  : 22
##  3rd Qu.:1.377e+10   3rd Qu.: 685.0   3rd Qu.:1.00   1082   : 22
##  Max.   :2.179e+10   Max.   :1131.0   Max.   :1.00   1111X  : 22
##                                                      (Other):968
##     Max_Temp        Min_Temp        Mean_Temp     Mean_Temp_lag8
##  Min.   : 3.10   Min.   :-4.700   Min.   : 1.00   Min.   : 5.763
##  1st Qu.:13.80   1st Qu.: 3.300   1st Qu.: 8.90   1st Qu.:10.162
##  Median :16.60   Median : 6.400   Median :11.40   Median :11.994
##  Mean   :16.25   Mean   : 6.293   Mean   :11.27   Mean   :12.207
##  3rd Qu.:19.00   3rd Qu.: 9.100   3rd Qu.:13.60   3rd Qu.:13.981
##  Max.   :25.50   Max.   :18.100   Max.   :21.00   Max.   :19.887
##
##  Mean_Temp_lag11  Mean_Temp_lag11w Sunshine_Hours   Sunshine_Hours_lag8
##  Min.   : 5.364   Min.   : 4.201   Min.   : 0.000   Min.   : 0.7125
##  1st Qu.:10.007   1st Qu.: 9.838   1st Qu.: 2.275   1st Qu.: 4.9594
##  Median :12.000   Median :11.764   Median : 6.350   Median : 6.4500
##  Mean   :12.062   Mean   :11.951   Mean   : 5.972   Mean   : 6.4370
##  3rd Qu.:13.718   3rd Qu.:14.006   3rd Qu.: 9.500   3rd Qu.: 8.0906
##  Max.   :19.636   Max.   :19.402   Max.   :12.400   Max.   :10.9375
##
##  Sunshine_Hours_lag11 Sunshine_Hours_lag11w Precipitation    Precipitation_lag8
##  Min.   : 1.582       Min.   : 1.115        Min.   :0.0000   Min.   :0.0000
##  1st Qu.: 5.145       1st Qu.: 4.766        1st Qu.:0.0000   1st Qu.:0.1250
##  Median : 6.305       Median : 6.377        Median :0.0000   Median :0.3750
##  Mean   : 6.317       Mean   : 6.368        Mean   :0.4491   Mean   :0.3516
##  3rd Qu.: 7.623       3rd Qu.: 8.037        3rd Qu.:1.0000   3rd Qu.:0.5000
##  Max.   :10.136       Max.   :11.041        Max.   :1.0000   Max.   :1.0000
##
##  Precipitation_lag11 Precipitation_lag11w    Humidity      Humidity_lag8
##  Min.   :0.0000      Min.   :0.0000       Min.   :  2.00   Min.   :40.24
##  1st Qu.:0.2727      1st Qu.:0.1584       1st Qu.: 69.82   1st Qu.:69.42
##  Median :0.3636      Median :0.3668       Median : 77.78   Median :75.82
##  Mean   :0.3682      Mean   :0.3593       Mean   : 77.02   Mean   :74.88
##  3rd Qu.:0.5455      3rd Qu.:0.5489       3rd Qu.: 84.70   3rd Qu.:80.80
##  Max.   :1.0000      Max.   :1.0000       Max.   :100.00   Max.   :94.61
##
##  Humidity_lag11  Humidity_lag11w          geometry
##  Min.   :42.24   Min.   :41.57   MULTIPOLYGON :1100
##  1st Qu.:70.74   1st Qu.:70.06   epsg:4326    :   0
```

```
##  Median :75.72   Median :76.31   +proj=long...:   0
##  Mean   :75.37   Mean   :75.49
##  3rd Qu.:80.60   3rd Qu.:81.13
##  Max.   :93.36   Max.   :94.04
##
```

The dataframe is a simple features object with information at the level of the province. The dataframe includes information about the province, including its Autonomous Community (a superior jurisdiction), an identifier, dates, COVID-19 cases and incidence. The period covered is from March 14, 2020 to April 4, 2020. In addition there are some demographic controls, and various climatic variables. Of interest are the lagged variables. The lagged variables are 8-day moving averages calculated using date-minus-12-days to date-minus-5-days, to account for the latency of the infection. More information about the dataset can be obtained by typing `?covid18_spain`.

There are 50 provinces in Spain:

```
nlevels(covid19_spain$province)
```

```
## [1] 50
```

Shelter in place order in Spain went into effect on March 16, 2020. March 14 is the first day that every province had at least one reported case of COVID-19.

Calculate population density and convert GDP per capita to thousands of euros:

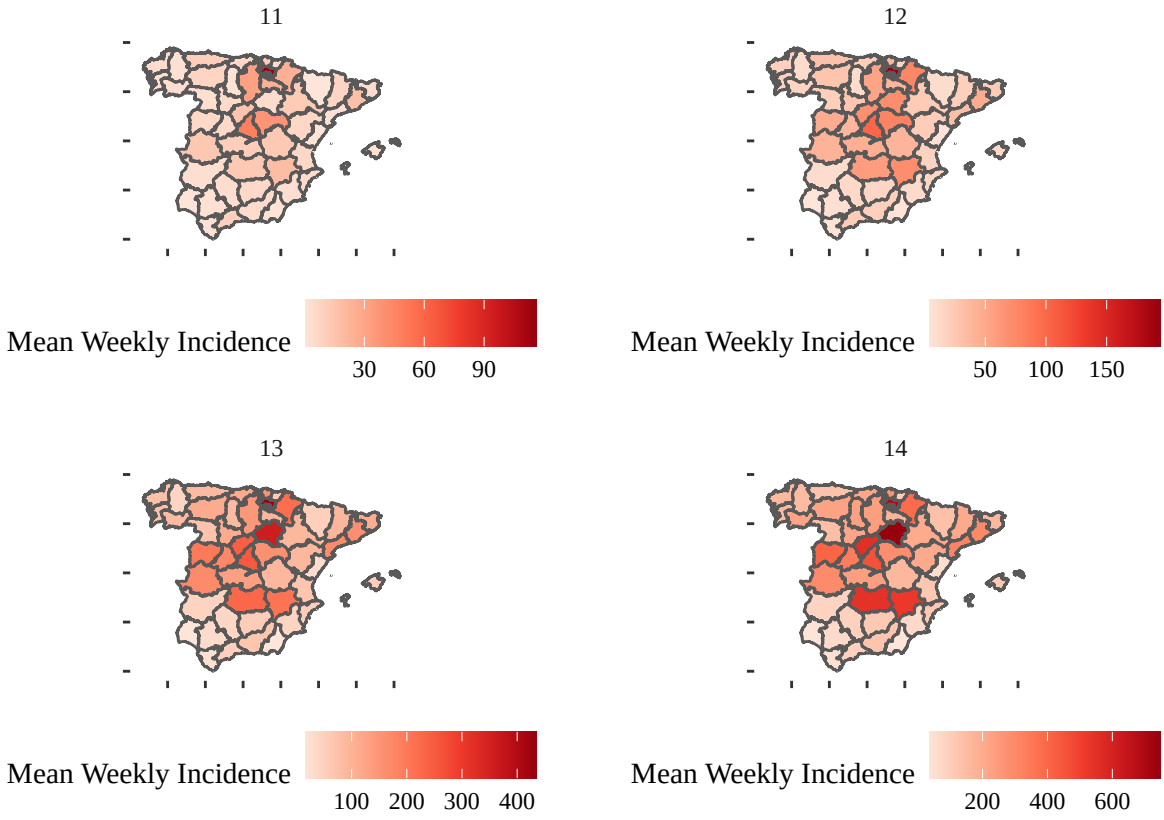
```
covid19_spain <- covid19_spain %>%
  mutate(GDPpc = GDPpc/1000,
         Density = Population/units::set_units(st_area(covid19_spain), km^2))
```

Data visualization

There are 22 days in the dataset. We can summarize the incidence by week (excluding Canarias):

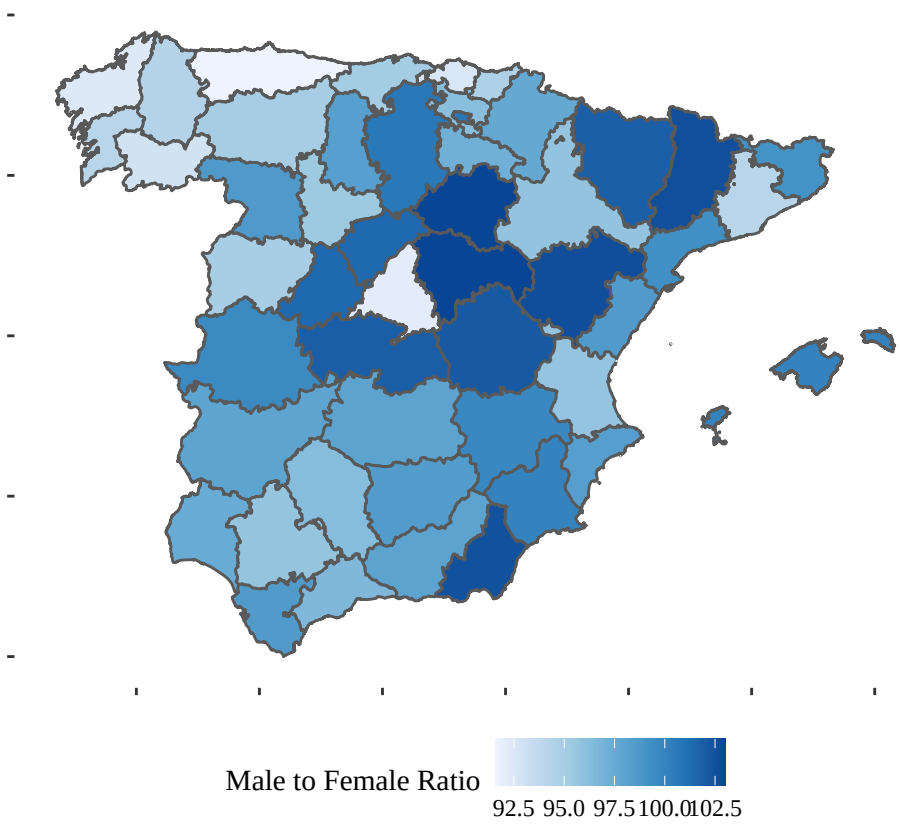
```
week11.plot <- covid19_spain %>%
  filter(CCAA != "Canarias") %>%
  group_by(province, week = isoweek(Date)) %>%
  summarise(mean_weekly_incidence = mean(Incidence)) %>%
  filter(week == 11) %>%
  ggplot() +
  geom_sf(aes(fill = mean_weekly_incidence)) +
  scale_fill_distiller(name = "Mean Weekly Incidence",
                       palette = "Reds",
                       direction = 1) +
  theme_tufte() +
  theme(axis.text = element_blank(),
        legend.position = "bottom") +
  facet_wrap(~week)

week12.plot <- covid19_spain %>%
  filter(CCAA != "Canarias") %>%
  group_by(province, week = isoweek(Date)) %>%
  summarise(mean_weekly_incidence = mean(Incidence)) %>%
  filter(week == 12) %>%
  ggplot() +
  geom_sf(aes(fill = mean_weekly_incidence)) +
  scale_fill_distiller(name = "Mean Weekly Incidence",
                       palette = "Reds",
```

```
                        direction = 1) +
  theme_tufte() +
  theme(axis.text = element_blank(),
        legend.position = "bottom") +
  facet_wrap(~week)

week13.plot <- covid19_spain %>%
  filter(CCAA != "Canarias") %>%
  group_by(province, week = isoweek(Date)) %>%
  summarise(mean_weekly_incidence = mean(Incidence)) %>%
  filter(week == 13) %>%
  ggplot() +
  geom_sf(aes(fill = mean_weekly_incidence)) +
  scale_fill_distiller(name = "Mean Weekly Incidence",
                       palette = "Reds",
                       direction = 1) +
  theme_tufte() +
  theme(axis.text = element_blank(),
        legend.position = "bottom") +
  facet_wrap(~week)

week14.plot <- covid19_spain %>%
  filter(CCAA != "Canarias") %>%
  group_by(province, week = isoweek(Date)) %>%
  summarise(mean_weekly_incidence = mean(Incidence)) %>%
  filter(week == 14) %>%
  ggplot() +
  geom_sf(aes(fill = mean_weekly_incidence)) +
  scale_fill_distiller(name = "Mean Weekly Incidence",
                       palette = "Reds",
                       direction = 1) +
  theme_tufte() +
  theme(axis.text = element_blank(),
        legend.position = "bottom") +
  facet_wrap(~week)

grid.arrange(week11.plot, week12.plot, week13.plot, week14.plot, nrow = 2)
```



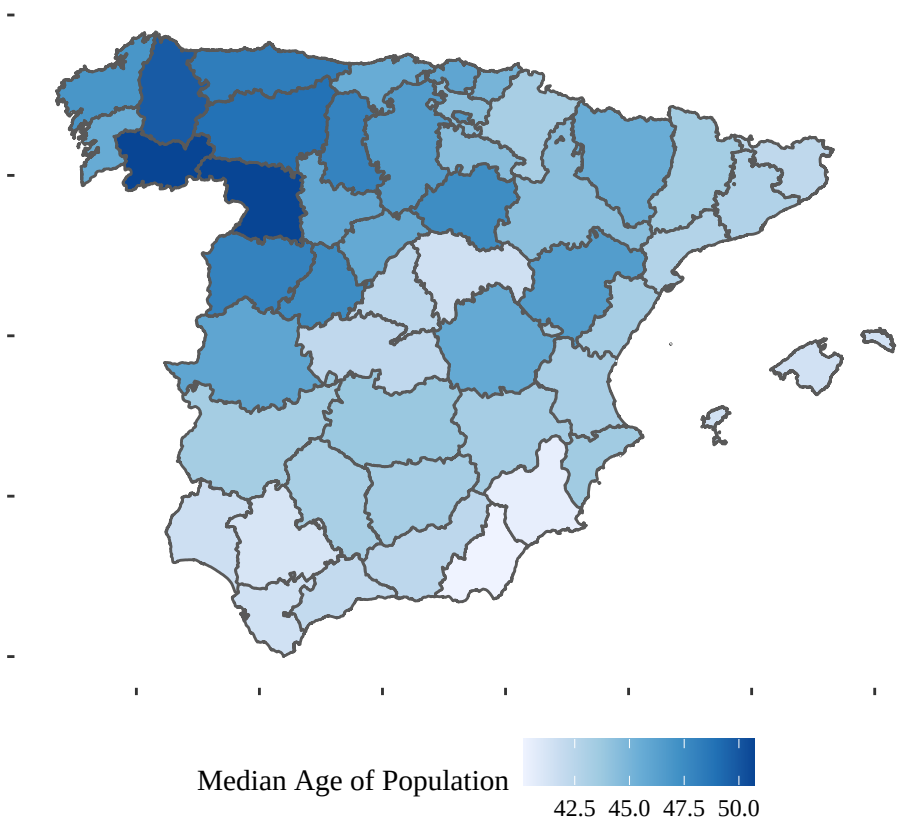
We consider some control variables: ratio of male to female in the province, and median age of the population, population density, and GDP per capita:

```
covid19_spain %>%
  filter(CCAA != "Canarias", Date == "2020-03-14") %>%
  ggplot() +
  geom_sf(aes(fill = Male2Female)) +
  scale_fill_distiller(name = "Male to Female Ratio",
                       palette = "Blues",
                       direction = 1) +
  theme_tufte() +
  theme(axis.text = element_blank(),
        legend.position = "bottom")
```



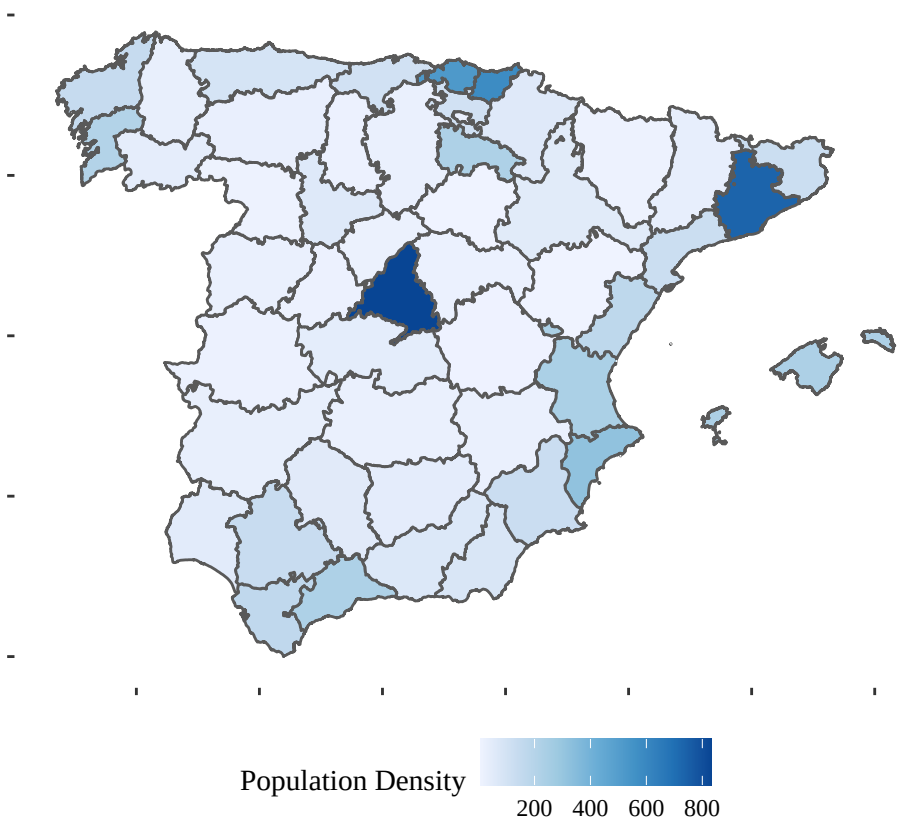
Median age of the population:

```
covid19_spain %>%
  filter(CCAA != "Canarias", Date == "2020-03-14") %>%
  ggplot() +
  geom_sf(aes(fill = Median_Age)) +
  scale_fill_distiller(name = "Median Age of Population",
                       palette = "Blues",
                       direction = 1) +
  theme_tufte() +
  theme(axis.text = element_blank(),
        legend.position = "bottom")
```



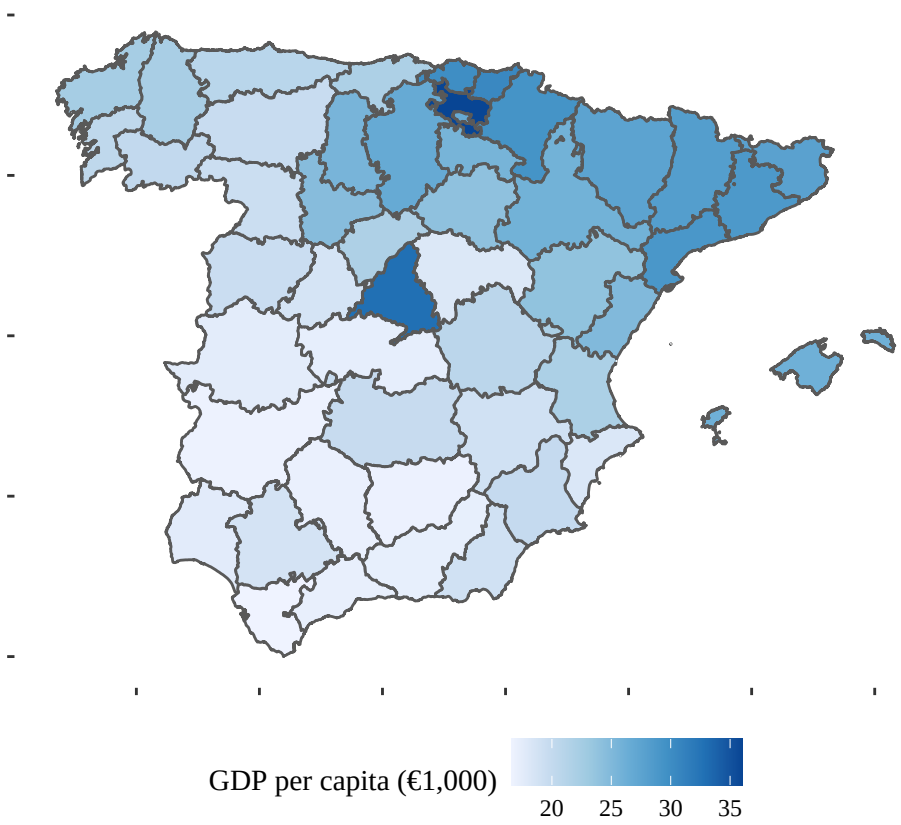
Population density:

```
covid19_spain %>%
  filter(CCAA != "Canarias", Date == "2020-03-14") %>%
  ggplot() +
  geom_sf(aes(fill = as.numeric(Density))) +
  scale_fill_distiller(name = "Population Density",
                       palette = "Blues",
                       direction = 1) +
  theme_tufte() +
  theme(axis.text = element_blank(),
        legend.position = "bottom")
```



Population density:

```
covid19_spain %>%
  filter(CCAA != "Canarias", Date == "2020-03-14") %>%
  ggplot() +
  geom_sf(aes(fill = as.numeric(GDPpc))) +
  scale_fill_distiller(name = "GDP per capita (€1,000)",
                       palette = "Blues",
                       direction = 1) +
  theme_tufte() +
  theme(axis.text = element_blank(),
        legend.position = "bottom")
```



We are also interested in the climatic variables. The following plot is the distribution of temperature by CCAA:

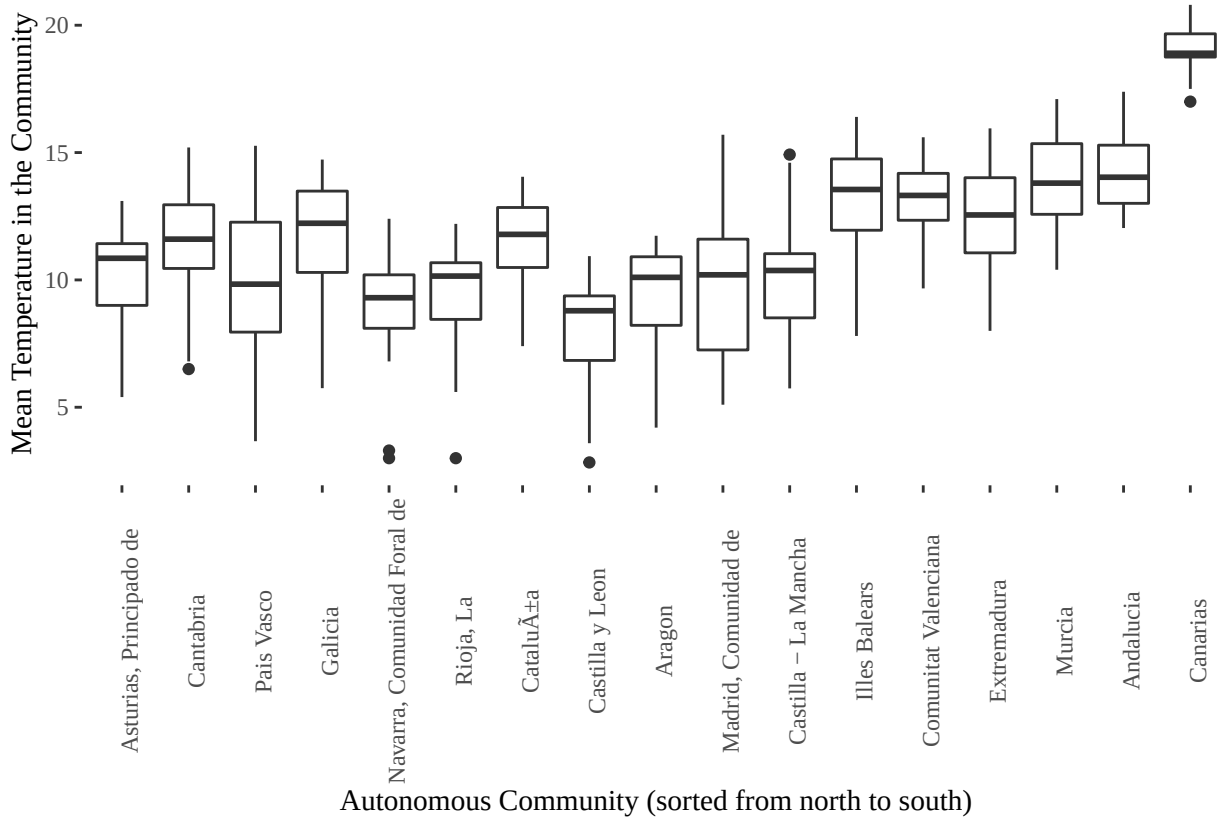
```
# Autonomous communities
ccaa.sf <- covid19_spain %>%
  filter(Date == "2020-03-14") %>%
  group_by(CCAA) %>%
  summarize(provinces = n())

# Extract coordinates of autonomous communities
ccaa.coords <- ccaa.sf %>%
  st_centroid() %>%
  st_coordinates() %>%
  as.data.frame()
```

```
## Warning in st_centroid.sf(.): st_centroid assumes attributes are constant over
## geometries of x
```

```
## Warning in st_centroid.sfc(st_geometry(x), of_largest_polygon =
## of_largest_polygon): st_centroid does not give correct centroids for longitude/
## latitude data
```

```
# Join Y coordinate to ccaa.sf
ccaa.sf <- ccaa.sf %>%
  mutate(long = ccaa.coords$Y)

# Sort autonomous communities from north to south
ccaa.levels <- ccaa.sf %>%
```

```
  arrange(desc(long)) %>% select(CCAA)

ccaa.levels <- as.character(ccaa.levels$CCAA)

# Relevel autonomous communities
covid19_spain <- covid19_spain %>%
  mutate(CCAA = factor(CCAA, levels = ccaa.levels, ordered = TRUE))

# Boxplots of temperatures
covid19_spain %>%
  st_drop_geometry() %>%
  group_by(CCAA, Date) %>%
  summarize(Mean_Temp = mean(Mean_Temp)) %>%
  ggplot(aes(x = CCAA, y = Mean_Temp)) +
  geom_boxplot() +
  theme_tufte() +
  theme(axis.text.x = element_text(angle = 90)) +
  xlab("Autonomous Community (sorted from north to south)") +
  ylab("Mean Temperature in the Community")
```



Multivariate analysis: comparison of approaches

Panel

1) Panel clásico
2) Panel Clásico o Dinámico

- Debe ser un modelo de efectos fijos para recoger la hetereogeneidad entre las distintas provincias (efectos)
- Debería incluir estructura dinámica ya que la serie tiene una fuerte estrutura temporal
- INCONVENIENTE: considera que la incluencia del dato del día anterior es constante (se estima un coeficiente constante)
- INCONVENIENTE: No se pueden incluir varaibles constantes en T. La hetereogeneidad entre provincias queda en el efecto fijo. No podemos por tanto incluir datos sobre estructura de la poblacion.
- INCONVENIENTE: No podemos incorporar efectos espaciales. El paquete **splm** no incluye estimación de paneles dinámicos con efectos espaciales. Tendriamos que hacerlo en matlab con los códigos de P.Elhorst.

Spatial SUR

2) SUR espacial

- Hay un coeficente para cada variable y cada instante de tiempo. Aunque es posible considerar coeficientes constantes para los periodos temporales que consideremos.
- La hetereoeneidad espacial debemos incorporarla mediante variables explicativas. –> Estructura de la población relacionada con COVID-19.
- Permite incluir varaibles constantes en T.
- la dinámica temporar quedará recogida mediante el término independiente y la estructura de correlaciones en los residuos. EN TODO CASO, ENTIENDO QUE NUESTRO OBJETIVO NO ES EXPLICAR ESA TENEDENCIA TEMPORAL (solo modelizarla para no incurrir en errores)

Prepare data for SUR analysis

*El modelo debe considerar efectos del 'individuo' y del 'tiempo' (para incorporar tendencia temporal)**

```
# Definicion del panel para plm
GPanel <- plm::pdata.frame(covid19_spain %>%
                             st_drop_geometry() %>%
                             select(province,
                                    Date,
                                    Incidence,
                                    Median_Age,
                                    Male2Female,
                                    Density,
                                    Transit,
                                    Mean_Temp_lag8,
                                    Humidity_lag8,
                                    Sunshine_Hours_lag8,
                                    Mean_Temp_lag11,
                                    Humidity_lag11,
                                    Sunshine_Hours_lag11,
                                    Mean_Temp_lag11w,
                                    Humidity_lag11w,
                                    Sunshine_Hours_lag11w),
                           c("province","Date"))
```

Spatial SUR model

Create connectivity matrix:

```
# Spatial weights matrix:
Wmat <- covid19_spain %>%
  filter(Date == "2020-03-14") %>%
```

```
  as("Spatial") %>%
  poly2nb(queen = FALSE) %>%
  nb2mat(zero.policy = T)

Wmat <- (Wmat > 0) * 1

# Join the two provinces in Canarias
Wmat[37, 44] <- 1
Wmat[44, 37] <- 1

# 'Paises Catalans'
n = 8
Wmat[9,n] <- 1
Wmat[n,9] <- 1
Wmat[n,47] <- 1
Wmat[47,n] <- 1
Wmat[n,43] <- 1
Wmat[43,n] <- 1
miW <- Wmat/rowSums(Wmat)

# Convert to listw
listw <- mat2listw(Wmat,style = "W")
```

Define formulas with three different lagged variables:

```
formula_lag8 <- log(Incidence) ~ log(Male2Female) +
  log(Median_Age) +
  log(Density) +
  Transit +
  log(Humidity_lag8) +
  log(Mean_Temp_lag8)

formula_lag11 <- log(Incidence) ~ log(Male2Female) +
  log(Median_Age) +
  log(Density) +
  Transit +
  log(Humidity_lag11) +
  log(Mean_Temp_lag11)

formula_lag11w <- log(Incidence) ~ log(Male2Female) +
  log(Median_Age) +
  log(Density) +
  Transit +
  log(Humidity_lag11w) +
  log(Mean_Temp_lag11w)
```

Create the terms needed to impose restrictions to the parameters for estimation. In this case we will restrict the two demographic variables and let Density, Transit, and the climatic variables to vary across equations. The rationale is that age and ratio of male to female do not change in the short period of time examined; on the other hand, while density and the presence of transit systems are also constants over the period examined, the behavior changed as a consequence of the lockdown: we expect these variables to be significant early on in the evolution of the pandemic, and become non-significant as the lockdown reduces their importance for the transmission of the virus.

```r
T <- 22 # Number of time periods, i.e., equations
k <- 7 # Number of independent variables, including the constant
coef_rest <- 2 # Number of restrictions

# nrow is number of equations (time periods) minus 1, times the number of restrictions
# ncol is number of variables times number of equations
R2 <- matrix(0, nrow = (T - 1) * coef_rest, ncol = k * 22)

for (i in 1:(T-1)){
  R2[i, 2] <- 1
  R2[i, (2 + i * k)] <- -1
  R2[(i + T - 1), 3] <- 1
  R2[(i + T - 1), (3 + i * k)] <- -1
  # Use if more restrictions are needed
  #R2[(i + T - 1) * 2, 4] <- 1
  #R2[(i + T - 1) * 2, (4 + i * k)] <- -1
}
b2 <- matrix(0, ncol = 21*coef_rest)
```

Model with a lagged 8-day moving average of climatic variables:

```r
sur.slm_lag8 <- spsur::spsurtime(formula = formula_lag8,
                                 data=GPanel,
                                 time = GPanel$Date,
                                 type = "slm",
                                 fit_method = "3sls",
                                 listw=  listw,
                                 R = R2,
                                 b = b2)
```

```
## Time to fit the model:  0.41  seconds
```

```r
summary(sur.slm_lag8)
```

```
## Call:
## spsur::spsurtime(formula = formula_lag8, data = GPanel, time = GPanel$Date,
##     listw = listw, type = "slm", fit_method = "3sls", R = R2,
##     b = b2)
##
##
## Spatial SUR model type:  slm
##
## Equation  1
##                          Estimate Std. Error t value Pr(>|t|)
## (Intercept)_1           15.646941  14.960884  1.0459  0.29598
## log(Male2Female)_1      -2.315769   2.346990 -0.9867  0.32413
## log(Median_Age)_1       -0.005798   1.275087 -0.0045  0.99637
## log(Density)_1           0.084401   0.149345  0.5651  0.57216
## Transit_1                0.471310   0.501833  0.9392  0.34796
## log(Humidity_lag8)_1    -0.295667   0.484401 -0.6104  0.54181
## log(Mean_Temp_lag8)_1 -1.064301   0.413557 -2.5735  0.01027 *
## rho_1                    0.069636   0.161118  0.4322  0.66572
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.2052
```

```
##   Equation  2
##                          Estimate Std. Error t value Pr(>|t|)
## (Intercept)_2          17.781542  14.936491  1.1905 0.234255
## log(Density)_2          0.041601   0.130975  0.3176 0.750860
## Transit_2               0.496568   0.443735  1.1191 0.263490
## log(Humidity_lag8)_2   -0.579457   0.431160 -1.3439 0.179392
## log(Mean_Temp_lag8)_2 -1.196113   0.363106 -3.2941 0.001036 **
## rho_2                   0.050914   0.130660  0.3897 0.696897
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.2325
##   Equation  3
##                          Estimate Std. Error t value Pr(>|t|)
## (Intercept)_3          16.959341  14.932092  1.1358 0.256437
## log(Density)_3         -0.031208   0.116796 -0.2672 0.789389
## Transit_3               0.555012   0.394186  1.4080 0.159569
## log(Humidity_lag8)_3   -0.411733   0.363792 -1.1318 0.258107
## log(Mean_Temp_lag8)_3 -1.027912   0.313904 -3.2746 0.001109 **
## rho_3                   0.189370   0.106663  1.7754 0.076257 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.2748
##   Equation  4
##                          Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_4          17.744987  14.886359  1.1920 0.2336461
## log(Density)_4         -0.073432   0.114016 -0.6441 0.5197487
## Transit_4               0.552868   0.385986  1.4324 0.1524812
## log(Humidity_lag8)_4   -0.504770   0.340819 -1.4811 0.1390348
## log(Mean_Temp_lag8)_4 -1.061558   0.294000 -3.6107 0.0003267 ***
## rho_4                   0.196280   0.093713  2.0945 0.0365699 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.2797
##   Equation  5
##                         Estimate Std. Error t value Pr(>|t|)
## (Intercept)_5          17.49096   14.90758  1.1733  0.24107
## log(Density)_5         -0.13584    0.11790 -1.1521  0.24965
## Transit_5               0.60758    0.40526  1.4992  0.13426
## log(Humidity_lag8)_5   -0.45223    0.37660 -1.2008  0.23022
## log(Mean_Temp_lag8)_5 -0.91055    0.30660 -2.9698  0.00308 **
## rho_5                   0.24466    0.09376  2.6094  0.00926 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.2465
##   Equation  6
##                          Estimate Std. Error t value Pr(>|t|)
## (Intercept)_6          20.344105  14.795169  1.3751  0.16955
## log(Density)_6         -0.108670   0.112071 -0.9696  0.33255
## Transit_6               0.554761   0.381083  1.4557  0.14590
## log(Humidity_lag8)_6   -0.611421   0.283132 -2.1595  0.03114 *
## log(Mean_Temp_lag8)_6 -1.150993   0.246279 -4.6735 3.54e-06 ***
## rho_6                  -0.197133   0.091666 -2.1506  0.03185 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
## R-squared: 0.2095
##   Equation  7
##                          Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_7          19.954047  14.792466  1.3489   0.17779
## log(Density)_7         -0.180987   0.105969 -1.7079   0.08809 .
## Transit_7               0.569538   0.355620  1.6015   0.10970
## log(Humidity_lag8)_7  -0.547194   0.272450 -2.0084   0.04498 *
## log(Mean_Temp_lag8)_7 -1.103245   0.224117 -4.9226 1.062e-06 ***
## rho_7                 -0.015585   0.093513 -0.1667   0.86768
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.2474
##   Equation  8
##                          Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_8          19.289551  14.781201  1.3050   0.19231
## log(Density)_8         -0.199708   0.107327 -1.8607   0.06319 .
## Transit_8               0.598780   0.361683  1.6555   0.09825 .
## log(Humidity_lag8)_8  -0.313151   0.258046 -1.2135   0.22532
## log(Mean_Temp_lag8)_8 -1.172006   0.215747 -5.4323 7.639e-08 ***
## rho_8                  0.011985   0.092930  0.1290   0.89742
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.2811
##   Equation  9
##                            Estimate  Std. Error t value  Pr(>|t|)
## (Intercept)_9          18.23895301 14.77852127  1.2342    0.2176
## log(Density)_9         -0.15040438  0.10535682 -1.4276    0.1539
## Transit_9               0.51902041  0.35240027  1.4728    0.1412
## log(Humidity_lag8)_9  -0.10258239  0.27159497 -0.3777    0.7058
## log(Mean_Temp_lag8)_9 -1.13821157  0.22066608 -5.1581 3.237e-07 ***
## rho_9                 -0.00090695  0.09715795 -0.0093    0.9926
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.2664
##   Equation  10
##                           Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_10         18.031378  14.758602  1.2218    0.2222
## log(Density)_10        -0.119123   0.098371 -1.2110    0.2263
## Transit_10              0.488828   0.319942  1.5279    0.1270
## log(Humidity_lag8)_10   0.133689   0.309869  0.4314    0.6663
## log(Mean_Temp_lag8)_10 -1.264528   0.221966 -5.6969 1.784e-08 ***
## rho_10                 -0.105625   0.095848 -1.1020    0.2708
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.3535
##   Equation  11
##                           Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_11         18.011239  14.699659  1.2253    0.2209
## log(Density)_11        -0.142547   0.094229 -1.5128    0.1308
## Transit_11              0.493916   0.300486  1.6437    0.1007
## log(Humidity_lag8)_11   0.124452   0.243676  0.5107    0.6097
## log(Mean_Temp_lag8)_11 -1.226865   0.194029 -6.3231 4.522e-10 ***
## rho_11                 -0.034986   0.082488 -0.4241    0.6716
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.3808
##   Equation  12
##                          Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_12         19.313237  14.704602  1.3134   0.18947
## log(Density)_12        -0.110907   0.094185 -1.1775   0.23937
## Transit_12              0.527627   0.296812  1.7776   0.07589 .
## log(Humidity_lag8)_12  -0.154413   0.257550 -0.5995   0.54900
## log(Mean_Temp_lag8)_12 -1.203378   0.182799 -6.5831 8.937e-11 ***
## rho_12                 -0.065670   0.078665 -0.8348   0.40411
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.3874
##   Equation  13
##                          Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_13         19.407684  14.683641  1.3217   0.18668
## log(Density)_13        -0.081212   0.089861 -0.9038   0.36643
## Transit_13              0.477781   0.273088  1.7496   0.08063 .
## log(Humidity_lag8)_13  -0.095185   0.258424 -0.3683   0.71274
## log(Mean_Temp_lag8)_13 -1.424959   0.184163 -7.7375 3.471e-14 ***
## rho_13                 -0.016433   0.075940 -0.2164   0.82874
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.4727
##   Equation  14
##                          Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_14         19.119015  14.667406  1.3035    0.1928
## log(Density)_14        -0.049977   0.092064 -0.5428    0.5874
## Transit_14              0.426373   0.278683  1.5300    0.1265
## log(Humidity_lag8)_14  -0.028026   0.279889 -0.1001    0.9203
## log(Mean_Temp_lag8)_14 -1.498136   0.204733 -7.3175 6.822e-13 ***
## rho_14                  0.013422   0.080921  0.1659    0.8683
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.4762
##   Equation  15
##                          Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_15         19.982150  14.645320  1.3644    0.1729
## log(Density)_15        -0.064865   0.091897 -0.7058    0.4805
## Transit_15              0.390664   0.275757  1.4167    0.1570
## log(Humidity_lag8)_15  -0.103498   0.248148 -0.4171    0.6767
## log(Mean_Temp_lag8)_15 -1.655752   0.197928 -8.3654 3.147e-16 ***
## rho_15                  0.031582   0.081098  0.3894    0.6971
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.5306
##   Equation  16
##                          Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_16         20.833111  14.610460  1.4259    0.1543
## log(Density)_16        -0.092552   0.092173 -1.0041    0.3157
## Transit_16              0.381563   0.279215  1.3666    0.1722
## log(Humidity_lag8)_16  -0.274871   0.253082 -1.0861    0.2778
## log(Mean_Temp_lag8)_16 -1.733592   0.213606 -8.1158 2.114e-15 ***
## rho_16                  0.108825   0.078224  1.3912    0.1646
```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.5138
##   Equation  17
##                          Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_17         21.809805  14.670028  1.4867   0.13754
## log(Density)_17        -0.115274   0.088965 -1.2957   0.19549
## Transit_17              0.449715   0.267973  1.6782   0.09374 .
## log(Humidity_lag8)_17  -0.486653   0.244506 -1.9904   0.04693 *
## log(Mean_Temp_lag8)_17 -1.644949   0.197283 -8.3380 3.888e-16 ***
## rho_17                  0.087651   0.071071  1.2333   0.21788
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.5152
##   Equation  18
##                          Estimate Std. Error t value Pr(>|t|)
## (Intercept)_18         21.734081  14.638676  1.4847  0.13806
## log(Density)_18        -0.148134   0.090061 -1.6448  0.10045
## Transit_18              0.500805   0.272980  1.8346  0.06698 .
## log(Humidity_lag8)_18  -0.576296   0.237966 -2.4218  0.01569 *
## log(Mean_Temp_lag8)_18 -1.329986   0.177222 -7.5046 1.84e-13 ***
## rho_18                  0.055564   0.081439  0.6823  0.49529
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.4936
##   Equation  19
##                          Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_19         18.059291  14.708608  1.2278    0.2199
## log(Density)_19        -0.122887   0.088889 -1.3825    0.1673
## Transit_19              0.215235   0.265906  0.8094    0.4185
## log(Humidity_lag8)_19   0.220094   0.312617  0.7040    0.4816
## log(Mean_Temp_lag8)_19 -1.271467   0.181074 -7.0218 5.115e-12 ***
## rho_19                  0.054462   0.101983  0.5340    0.5935
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.5012
##   Equation  20
##                           Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_20         21.5221364 14.6456795  1.4695  0.142133
## log(Density)_20        -0.1664341  0.0884059 -1.8826  0.060160 .
## Transit_20              0.5279216  0.2662180  1.9830  0.047746 *
## log(Humidity_lag8)_20  -0.5483454  0.2069142 -2.6501  0.008225 **
## log(Mean_Temp_lag8)_20 -1.1210658  0.1502312 -7.4623 2.482e-13 ***
## rho_20                  0.0019628  0.0844246  0.0232  0.981458
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.5042
##   Equation  21
##                          Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_21         20.845024  14.678953  1.4201   0.15603
## log(Density)_21        -0.184475   0.085507 -2.1574   0.03131 *
## Transit_21              0.576428   0.254760  2.2626   0.02396 *
## log(Humidity_lag8)_21  -0.348664   0.208524 -1.6721   0.09495 .
## log(Mean_Temp_lag8)_21 -1.079831   0.141553 -7.6284 7.621e-14 ***
```

```
## rho_21                 -0.024316   0.085322 -0.2850   0.77573
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.5203
##   Equation  22
##                          Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_22         20.217899  14.664080  1.3787   0.16841
## log(Density)_22        -0.200018   0.086473 -2.3131   0.02100 *
## Transit_22              0.585310   0.259190  2.2582   0.02423 *
## log(Humidity_lag8)_22  -0.271002   0.195227 -1.3881   0.16553
## log(Mean_Temp_lag8)_22 -0.923003   0.125264 -7.3684 4.789e-13 ***
## rho_22                 -0.026087   0.089280 -0.2922   0.77022
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.5137
##
## Variance-Covariance Matrix of inter-equation residuals:
##  0.8375418 0.6958354 0.5921554 0.5521695 0.5452016 0.4971773 0.4359680
##  0.6958354 0.6582538 0.5524142 0.5279542 0.5154556 0.4564568 0.4100204
##  0.5921554 0.5524142 0.5214851 0.4974262 0.4902350 0.4273639 0.3870252
##  0.5521695 0.5279542 0.4974262 0.5008867 0.5045002 0.4472655 0.4031854
##  0.5452016 0.5154556 0.4902350 0.5045002 0.5543832 0.4888846 0.4422593
##  0.4971773 0.4564568 0.4273639 0.4472655 0.4888846 0.4917559 0.4471086
##  0.4359680 0.4100204 0.3870252 0.4031854 0.4422593 0.4471086 0.4274013
##  0.4416891 0.4044686 0.3817993 0.4009512 0.4393054 0.4486744 0.4268300
##  0.4281833 0.3853468 0.3637153 0.3837921 0.4225534 0.4313021 0.4096379
##  0.3617947 0.3356967 0.3016043 0.3256661 0.3676283 0.3741262 0.3579448
##  0.3225319 0.2956833 0.2798908 0.3076489 0.3392854 0.3542140 0.3358860
##  0.3016375 0.2771602 0.2623228 0.2907745 0.3133258 0.3349995 0.3176815
##  0.2414528 0.2260948 0.2124991 0.2341899 0.2458421 0.2711703 0.2599452
##  0.2182929 0.2066928 0.1925869 0.2109892 0.2127599 0.2369131 0.2283060
##  0.1789037 0.1771052 0.1574127 0.1763646 0.1756895 0.2014244 0.1922733
##  0.1692381 0.1776553 0.1588415 0.1741529 0.1765825 0.1972784 0.1912522
##  0.1930645 0.1949570 0.1724229 0.1807855 0.1848599 0.2018048 0.1978127
##  0.1982971 0.2087948 0.1940693 0.1995381 0.2026729 0.2117358 0.2100514
##  0.1897535 0.1945913 0.1900089 0.2017873 0.2017085 0.2131454 0.2038819
##  0.1894655 0.2009514 0.1949139 0.2035494 0.2048726 0.2145988 0.2095677
##  0.1868607 0.1954882 0.1898419 0.2009439 0.2032481 0.2145503 0.2099093
##  0.2059915 0.2110601 0.2061653 0.2182945 0.2224417 0.2329368 0.2278070
##
##  0.4416891 0.4281833 0.3617947 0.3225319 0.3016375 0.2414528 0.2182929
##  0.4044686 0.3853468 0.3356967 0.2956833 0.2771602 0.2260948 0.2066928
##  0.3817993 0.3637153 0.3016043 0.2798908 0.2623228 0.2124991 0.1925869
##  0.4009512 0.3837921 0.3256661 0.3076489 0.2907745 0.2341899 0.2109892
##  0.4393054 0.4225534 0.3676283 0.3392854 0.3133258 0.2458421 0.2127599
##  0.4486744 0.4313021 0.3741262 0.3542140 0.3349995 0.2711703 0.2369131
##  0.4268300 0.4096379 0.3579448 0.3358860 0.3176815 0.2599452 0.2283060
##  0.4416625 0.4235388 0.3687981 0.3480893 0.3285269 0.2653952 0.2315229
##  0.4235388 0.4183624 0.3635647 0.3423545 0.3261549 0.2655820 0.2366328
##  0.3687981 0.3635647 0.3429746 0.3114013 0.2975710 0.2468315 0.2197065
##  0.3480893 0.3423545 0.3114013 0.3018815 0.2915947 0.2459911 0.2230142
##  0.3285269 0.3261549 0.2975710 0.2915947 0.2944105 0.2579455 0.2411275
##  0.2653952 0.2655820 0.2468315 0.2459911 0.2579455 0.2478344 0.2440527
##  0.2315229 0.2366328 0.2197065 0.2230142 0.2411275 0.2440527 0.2570309
```

```
##  0.1949029 0.2006995 0.1908220 0.1918052 0.2119458 0.2242901 0.2439194
##  0.1902120 0.1941894 0.1866906 0.1845378 0.2019286 0.2177738 0.2369559
##  0.1971439 0.1990536 0.1882437 0.1809764 0.1955134 0.2082984 0.2219150
##  0.2095014 0.2087250 0.1927848 0.1848889 0.1950960 0.2037953 0.2144711
##  0.2074640 0.2023528 0.1842538 0.1826820 0.1896141 0.1933067 0.1987404
##  0.2107684 0.2091522 0.1899706 0.1855241 0.1969323 0.2001048 0.2083541
##  0.2136007 0.2113348 0.1912419 0.1861518 0.1963025 0.1931770 0.1971050
##  0.2334764 0.2301248 0.2074958 0.2019208 0.2095039 0.1989714 0.1980419
##
##  0.1789037 0.1692381 0.1930645 0.1982971 0.1897535 0.1894655 0.1868607
##  0.1771052 0.1776553 0.1949570 0.2087948 0.1945913 0.2009514 0.1954882
##  0.1574127 0.1588415 0.1724229 0.1940693 0.1900089 0.1949139 0.1898419
##  0.1763646 0.1741529 0.1807855 0.1995381 0.2017873 0.2035494 0.2009439
##  0.1756895 0.1765825 0.1848599 0.2026729 0.2017085 0.2048726 0.2032481
##  0.2014244 0.1972784 0.2018048 0.2117358 0.2131454 0.2145988 0.2145503
##  0.1922733 0.1912522 0.1978127 0.2100514 0.2038819 0.2095677 0.2099093
##  0.1949029 0.1902120 0.1971439 0.2095014 0.2074640 0.2107684 0.2136007
##  0.2006995 0.1941894 0.1990536 0.2087250 0.2023528 0.2091522 0.2113348
##  0.1908220 0.1866906 0.1882437 0.1927848 0.1842538 0.1899706 0.1912419
##  0.1918052 0.1845378 0.1809764 0.1848889 0.1826820 0.1855241 0.1861518
##  0.2119458 0.2019286 0.1955134 0.1950960 0.1896141 0.1969323 0.1963025
##  0.2242901 0.2177738 0.2082984 0.2037953 0.1933067 0.2001048 0.1931770
##  0.2439194 0.2369559 0.2219150 0.2144711 0.1987404 0.2083541 0.1971050
##  0.2512010 0.2492263 0.2295953 0.2213534 0.2038882 0.2108675 0.1963221
##  0.2492263 0.2588577 0.2425288 0.2377775 0.2151049 0.2240806 0.2071801
##  0.2295953 0.2425288 0.2389788 0.2379026 0.2137169 0.2223888 0.2069825
##  0.2213534 0.2377775 0.2379026 0.2489727 0.2269323 0.2357888 0.2202022
##  0.2038882 0.2151049 0.2137169 0.2269323 0.2343118 0.2214628 0.2090263
##  0.2108675 0.2240806 0.2223888 0.2357888 0.2214628 0.2361075 0.2237381
##  0.1963221 0.2071801 0.2069825 0.2202022 0.2090263 0.2237381 0.2163309
##  0.1929641 0.2006367 0.2016384 0.2177301 0.2083502 0.2225946 0.2173777
##
##  0.2059915
##  0.2110601
##  0.2061653
##  0.2182945
##  0.2224417
##  0.2329368
##  0.2278070
##  0.2334764
##  0.2301248
##  0.2074958
##  0.2019208
##  0.2095039
##  0.1989714
##  0.1980419
##  0.1929641
##  0.2006367
##  0.2016384
##  0.2177301
##  0.2083502
##  0.2225946
##  0.2173777
##  0.2242030
```

```
## Correlation Matrix of inter-equation residuals:
##  1.0000000 0.9442589 0.9091097 0.8746285 0.8423056 0.8134136 0.7822297
##  0.9442589 1.0000000 0.9512667 0.9368606 0.8897412 0.8307285 0.8156336
##  0.9091097 0.9512667 1.0000000 0.9797309 0.9328779 0.8731690 0.8620177
##  0.8746285 0.9368606 0.9797309 1.0000000 0.9630379 0.9084860 0.8931902
##  0.8423056 0.8897412 0.9328779 0.9630379 1.0000000 0.9324240 0.9160511
##  0.8134136 0.8307285 0.8731690 0.9084860 0.9324240 1.0000000 0.9797858
##  0.7822297 0.8156336 0.8620177 0.8931902 0.9160511 0.9797858 1.0000000
##  0.7735435 0.7905383 0.8389197 0.8730164 0.8964103 0.9702534 0.9876808
##  0.7719508 0.7824352 0.8237811 0.8594060 0.8866548 0.9601472 0.9767659
##  0.7294341 0.7568820 0.7695316 0.8149422 0.8615429 0.9292325 0.9521908
##  0.7147082 0.7355898 0.7784547 0.8316431 0.8623723 0.9440639 0.9632079
##  0.6742509 0.7008747 0.7487251 0.8062418 0.8279932 0.9230813 0.9452285
##  0.6243737 0.6596661 0.7069145 0.7589766 0.7728196 0.8757733 0.9093234
##  0.5998697 0.6433736 0.6903506 0.7372973 0.7336550 0.8299136 0.8669698
##  0.5583440 0.6102947 0.6455328 0.6980262 0.6947174 0.7881916 0.8243134
##  0.5580153 0.6195597 0.6501545 0.6972636 0.7032891 0.7867730 0.8285499
##  0.5952649 0.6446874 0.6687621 0.7083053 0.7174676 0.8080947 0.8520010
##  0.5814152 0.6459418 0.6804147 0.7143917 0.7197457 0.7989018 0.8463444
##  0.5625793 0.6081622 0.6675053 0.7111640 0.7068819 0.7887502 0.8205805
##  0.5535126 0.6173161 0.6694879 0.7078825 0.7141123 0.7966194 0.8398756
##  0.5590388 0.6167951 0.6708561 0.7108395 0.7180693 0.8040215 0.8497811
##  0.5653014 0.6251798 0.6802395 0.7210856 0.7289072 0.8168174 0.8619481
##
##  0.7735435 0.7719508 0.7294341 0.7147082 0.6742509 0.6243737 0.5998697
##  0.7905383 0.7824352 0.7568820 0.7355898 0.7008747 0.6596661 0.6433736
##  0.8389197 0.8237811 0.7695316 0.7784547 0.7487251 0.7069145 0.6903506
##  0.8730164 0.8594060 0.8149422 0.8316431 0.8062418 0.7589766 0.7372973
##  0.8964103 0.8866548 0.8615429 0.8623723 0.8279932 0.7728196 0.7336550
##  0.9702534 0.9601472 0.9292325 0.9440639 0.9230813 0.8757733 0.8299136
##  0.9876808 0.9767659 0.9521908 0.9632079 0.9452285 0.9093234 0.8669698
##  1.0000000 0.9890626 0.9628192 0.9758278 0.9587890 0.9187429 0.8732984
##  0.9890626 1.0000000 0.9702251 0.9786885 0.9642010 0.9249116 0.8861950
##  0.9628192 0.9702251 1.0000000 0.9761762 0.9616353 0.9273100 0.8842124
##  0.9758278 0.9786885 0.9761762 1.0000000 0.9873706 0.9580173 0.9221043
##  0.9587890 0.9642010 0.9616353 0.9873706 1.0000000 0.9806948 0.9518474
##  0.9187429 0.9249116 0.9273100 0.9580173 0.9806948 1.0000000 0.9853419
##  0.8732984 0.8861950 0.8842124 0.9221043 0.9518474 0.9853419 1.0000000
##  0.8336030 0.8453988 0.8547329 0.8833494 0.9199031 0.9628347 0.9797214
##  0.8344207 0.8416303 0.8532862 0.8725612 0.9050937 0.9497912 0.9626315
##  0.8617426 0.8665517 0.8729229 0.8858107 0.9145499 0.9538749 0.9591697
##  0.8551202 0.8575742 0.8562168 0.8701589 0.8931025 0.9309546 0.9374970
##  0.8365189 0.8296902 0.8167909 0.8510642 0.8689102 0.9019736 0.9026315
##  0.8497919 0.8544353 0.8455082 0.8672995 0.8969864 0.9287831 0.9360828
##  0.8630318 0.8677542 0.8553261 0.8769429 0.9053462 0.9295791 0.9320043
##  0.8755477 0.8792125 0.8665054 0.8888923 0.9134360 0.9291267 0.9271941
##
##  0.5583440 0.5580153 0.5952649 0.5814152 0.5625793 0.5535126 0.5590388
##  0.6102947 0.6195597 0.6446874 0.6459418 0.6081622 0.6173161 0.6167951
##  0.6455328 0.6501545 0.6687621 0.6804147 0.6675053 0.6694879 0.6708561
##  0.6980262 0.6972636 0.7083053 0.7143917 0.7111640 0.7078825 0.7108395
##  0.6947174 0.7032891 0.7174676 0.7197457 0.7068819 0.7141123 0.7180693
##  0.7881916 0.7867730 0.8080947 0.7989018 0.7887502 0.7966194 0.8040215
##  0.8243134 0.8285499 0.8520010 0.8463444 0.8205805 0.8398756 0.8497811
```

```
##  0.8336030 0.8344207 0.8617426 0.8551202 0.8365189 0.8497919 0.8630318
##  0.8453988 0.8416303 0.8665517 0.8575742 0.8296902 0.8544353 0.8677542
##  0.8547329 0.8532862 0.8729229 0.8562168 0.8167909 0.8455082 0.8553261
##  0.8833494 0.8725612 0.8858107 0.8701589 0.8510642 0.8672995 0.8769429
##  0.9199031 0.9050937 0.9145499 0.8931025 0.8689102 0.8969864 0.9053462
##  0.9628347 0.9497912 0.9538749 0.9309546 0.9019736 0.9287831 0.9295791
##  0.9797214 0.9626315 0.9591697 0.9374970 0.9026315 0.9360828 0.9320043
##  1.0000000 0.9918582 0.9818902 0.9640304 0.9302245 0.9595806 0.9512933
##  0.9918582 1.0000000 0.9921370 0.9811682 0.9366860 0.9710973 0.9620147
##  0.9818902 0.9921370 1.0000000 0.9885152 0.9418824 0.9760357 0.9708118
##  0.9640304 0.9811682 0.9885152 1.0000000 0.9556938 0.9907238 0.9852554
##  0.9302245 0.9366860 0.9418824 0.9556938 1.0000000 0.9555044 0.9512664
##  0.9595806 0.9710973 0.9760357 0.9907238 0.9555044 1.0000000 0.9967091
##  0.9512933 0.9620147 0.9708118 0.9852554 0.9512664 0.9967091 1.0000000
##  0.9416644 0.9501296 0.9599400 0.9778645 0.9431021 0.9902203 0.9962430
##
##  0.5653014
##  0.6251798
##  0.6802395
##  0.7210856
##  0.7289072
##  0.8168174
##  0.8619481
##  0.8755477
##  0.8792125
##  0.8665054
##  0.8888923
##  0.9134360
##  0.9291267
##  0.9271941
##  0.9416644
##  0.9501296
##  0.9599400
##  0.9778645
##  0.9431021
##  0.9902203
##  0.9962430
##  1.0000000
##
##  R-sq. pooled: 0.7724
##  Breusch-Pagan:  6618  p-value: (   0)
```

Model with 11-day moving average of climatic variables:

```
sur.slm_lag11 <- spsur::spsurtime(formula = formula_lag11,
                                  data=GPanel,
                                  time = GPanel$Date,
                                  type = "slm",
                                  fit_method = "3sls",
                                  listw=  listw,
                                 R = R2,
                                 b = b2)
```

```
## Time to fit the model:  0.34  seconds
```

```r
summary(sur.slm_lag11)
```

```
## Call:
## spsur::spsurtime(formula = formula_lag11, data = GPanel, time = GPanel$Date,
##     listw = listw, type = "slm", fit_method = "3sls", R = R2,
##     b = b2)
##
##
## Spatial SUR model type:  slm
##
## Equation  1
##                          Estimate Std. Error t value Pr(>|t|)
## (Intercept)_1          17.647933  16.295246  1.0830  0.27917
## log(Male2Female)_1     -2.059774   2.521149 -0.8170  0.41420
## log(Median_Age)_1      -0.610203   1.380688 -0.4420  0.65866
## log(Density)_1          0.035579   0.150354  0.2366  0.81301
## Transit_1               0.496907   0.508296  0.9776  0.32861
## log(Humidity_lag11)_1  -0.389543   0.560844 -0.6946  0.48755
## log(Mean_Temp_lag11)_1 -1.206883   0.539721 -2.2361  0.02565 *
## rho_1                   0.161816   0.187933  0.8610  0.38951
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.2144
##   Equation  2
##                           Estimate Std. Error t value Pr(>|t|)
## (Intercept)_2          19.4117083 16.1960996  1.1985  0.23110
## log(Density)_2         -0.0014819  0.1326806 -0.0112  0.99109
## Transit_2               0.5411757  0.4482616  1.2073  0.22773
## log(Humidity_lag11)_2  -0.6360825  0.4875624 -1.3046  0.19244
## log(Mean_Temp_lag11)_2 -1.2651806  0.4399427 -2.8758  0.00415 **
## rho_2                   0.1299603  0.1407512  0.9233  0.35615
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.2316
##   Equation  3
##                          Estimate Std. Error t value Pr(>|t|)
## (Intercept)_3          18.250165  16.156614  1.1296 0.259034
## log(Density)_3         -0.059453   0.120207 -0.4946 0.621043
## Transit_3               0.585691   0.400962  1.4607 0.144535
## log(Humidity_lag11)_3  -0.428696   0.430142 -0.9966 0.319279
## log(Mean_Temp_lag11)_3 -1.056244   0.347335 -3.0410 0.002444 **
## rho_3                   0.244073   0.114684  2.1282 0.033661 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.2741
##   Equation  4
##                          Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_4          19.336530  16.111169  1.2002 0.2304626
## log(Density)_4         -0.084519   0.118194 -0.7151 0.4747900
## Transit_4               0.565397   0.393916  1.4353 0.1516330
## log(Humidity_lag11)_4  -0.600443   0.411377 -1.4596 0.1448420
## log(Mean_Temp_lag11)_4 -1.134452   0.310412 -3.6547 0.0002764 ***
## rho_4                   0.267191   0.100507  2.6584 0.0080263 **
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.2803
##   Equation  5
##                          Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_5          18.770012  16.154359  1.1619 0.2456583
## log(Density)_5         -0.118423   0.120707 -0.9811 0.3268883
## Transit_5               0.596636   0.403309  1.4794 0.1394877
## log(Humidity_lag11)_5  -0.416866   0.462207 -0.9019 0.3674120
## log(Mean_Temp_lag11)_5 -1.123955   0.318732 -3.5263 0.0004483 ***
## rho_5                   0.291856   0.092629  3.1508 0.0016962 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.2703
##   Equation  6
##                          Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_6          20.491860  16.093029  1.2733    0.2033
## log(Density)_6         -0.081783   0.113811 -0.7186    0.4726
## Transit_6               0.522046   0.373575  1.3974    0.1627
## log(Humidity_lag11)_6  -0.304161   0.395718 -0.7686    0.4424
## log(Mean_Temp_lag11)_6 -1.415244   0.284914 -4.9673 8.507e-07 ***
## rho_6                  -0.142578   0.097444 -1.4632    0.1439
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.2663
##   Equation  7
##                           Estimate Std. Error t value Pr(>|t|)
## (Intercept)_7          19.2446872 16.0923119  1.1959   0.2321
## log(Density)_7         -0.1497994  0.1047517 -1.4300   0.1531
## Transit_7               0.5080283  0.3357777  1.5130   0.1307
## log(Humidity_lag11)_7   0.0034426  0.3449952  0.0100   0.9920
## log(Mean_Temp_lag11)_7 -1.3775787  0.2545928 -5.4109 8.57e-08 ***
## rho_7                  -0.0161183  0.0877598 -0.1837   0.8543
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.3335
##   Equation  8
##                          Estimate Std. Error t value Pr(>|t|)
## (Intercept)_8          20.553545  16.121059  1.2750   0.2027
## log(Density)_8         -0.166349   0.104876 -1.5861   0.1131
## Transit_8               0.533945   0.336432  1.5871   0.1129
## log(Humidity_lag11)_8  -0.144549   0.332249 -0.4351   0.6636
## log(Mean_Temp_lag11)_8 -1.619356   0.265682 -6.0951 1.79e-09 ***
## rho_8                   0.048567   0.086416  0.5620   0.5743
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.3768
##   Equation  9
##                          Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_9          20.486633  16.144921  1.2689    0.2049
## log(Density)_9         -0.119853   0.103160 -1.1618    0.2457
## Transit_9               0.475297   0.327393  1.4518    0.1470
## log(Humidity_lag11)_9  -0.183656   0.348716 -0.5267    0.5986
## log(Mean_Temp_lag11)_9 -1.568429   0.272190 -5.7623 1.235e-08 ***
## rho_9                   0.052487   0.095765  0.5481    0.5838
```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.3633
##   Equation  10
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)_10          20.5185114 16.1362468  1.2716   0.2039
## log(Density)_10         -0.0812890  0.0976475 -0.8325   0.4054
## Transit_10               0.4504390  0.2998828  1.5021   0.1335
## log(Humidity_lag11)_10  -0.0851258  0.3572486 -0.2383   0.8117
## log(Mean_Temp_lag11)_10 -1.6670461  0.2580290 -6.4607 1.93e-10 ***
## rho_10                   0.0033727  0.0926636  0.0364   0.9710
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.4342
##   Equation  11
##                            Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_11          19.474113  16.079423  1.2111    0.2263
## log(Density)_11         -0.097962   0.093533 -1.0474    0.2953
## Transit_11               0.427034   0.280427  1.5228    0.1283
## log(Humidity_lag11)_11   0.117900   0.287422  0.4102    0.6818
## log(Mean_Temp_lag11)_11 -1.602523   0.218499 -7.3342 6.076e-13 ***
## rho_11                   0.064974   0.079293  0.8194    0.4128
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.4637
##   Equation  12
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)_12          20.357275  16.042105  1.2690   0.2049
## log(Density)_12         -0.079131   0.096233 -0.8223   0.4112
## Transit_12               0.469000   0.289727  1.6188   0.1059
## log(Humidity_lag11)_12  -0.087422   0.299908 -0.2915   0.7708
## log(Mean_Temp_lag11)_12 -1.501391   0.218711 -6.8647 1.45e-11 ***
## rho_12                   0.021083   0.081908  0.2574   0.7969
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.4396
##   Equation  13
##                            Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_13          19.760961  16.032479  1.2326    0.2181
## log(Density)_13         -0.065196   0.093387 -0.6981    0.4853
## Transit_13               0.447935   0.275343  1.6268    0.1042
## log(Humidity_lag11)_13   0.089924   0.308864  0.2911    0.7710
## log(Mean_Temp_lag11)_13 -1.612768   0.223465 -7.2171 1.363e-12 ***
## rho_13                   0.062188   0.082948  0.7497    0.4537
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.4885
##   Equation  14
##                            Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_14          19.490574  16.020506  1.2166    0.2242
## log(Density)_14         -0.063243   0.095332 -0.6634    0.5073
## Transit_14               0.437959   0.283020  1.5474    0.1222
## log(Humidity_lag11)_14   0.119090   0.322782  0.3689    0.7123
## log(Mean_Temp_lag11)_14 -1.530234   0.238823 -6.4074 2.689e-10 ***
```

```
## rho_14                   0.065311   0.086965  0.7510    0.4529
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.4703
##   Equation  15
##                           Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_15          21.736297  15.978532  1.3603   0.17415
## log(Density)_15         -0.106050   0.092713 -1.1438   0.25307
## Transit_15               0.453208   0.273892  1.6547   0.09843 .
## log(Humidity_lag11)_15  -0.353589   0.282020 -1.2538   0.21034
## log(Mean_Temp_lag11)_15 -1.546650   0.203426 -7.6030 9.142e-14 ***
## rho_15                   0.100354   0.084782  1.1837   0.23694
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.515
##   Equation  16
##                           Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_16          22.456454  15.970943  1.4061   0.16014
## log(Density)_16         -0.125298   0.090941 -1.3778   0.16870
## Transit_16               0.426926   0.267706  1.5948   0.11121
## log(Humidity_lag11)_16  -0.536355   0.259884 -2.0638   0.03940 *
## log(Mean_Temp_lag11)_16 -1.527315   0.193645 -7.8872 1.162e-14 ***
## rho_16                   0.141947   0.083825  1.6934   0.09082 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.5201
##   Equation  17
##                           Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_17          23.298431  15.991479  1.4569  0.145577
## log(Density)_17         -0.131215   0.089344 -1.4686  0.142369
## Transit_17               0.473556   0.261107  1.8136  0.070152 .
## log(Humidity_lag11)_17  -0.692359   0.242164 -2.8591  0.004373 **
## log(Mean_Temp_lag11)_17 -1.441412   0.179744 -8.0192 4.364e-15 ***
## rho_17                   0.083616   0.081369  1.0276  0.304475
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared:  0.52
##   Equation  18
##                           Estimate Std. Error t value Pr(>|t|)
## (Intercept)_18          23.555389  15.970862  1.4749 0.140681
## log(Density)_18         -0.142071   0.090054 -1.5776 0.115097
## Transit_18               0.500339   0.263294  1.9003 0.057796 .
## log(Humidity_lag11)_18  -0.706442   0.241654 -2.9234 0.003572 **
## log(Mean_Temp_lag11)_18 -1.372054   0.179515 -7.6431 6.86e-14 ***
## rho_18                   0.030015   0.089296  0.3361 0.736873
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.5225
##   Equation  19
##                           Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_19          19.593103  15.995483  1.2249    0.2210
## log(Density)_19         -0.131347   0.090624 -1.4494    0.1477
## Transit_19               0.227202   0.263619  0.8619    0.3891
## log(Humidity_lag11)_19   0.086313   0.348519  0.2477    0.8045
```

```
## log(Mean_Temp_lag11)_19 -1.232376   0.181271 -6.7985 2.236e-11 ***
## rho_19                   0.068430   0.106915  0.6400    0.5224
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.5008
##   Equation  20
##                          Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_20          21.912413  15.917799  1.3766   0.16907
## log(Density)_20         -0.170046   0.089201 -1.9063   0.05701 .
## Transit_20               0.538845   0.259806  2.0740   0.03843 *
## log(Humidity_lag11)_20  -0.389967   0.229102 -1.7022   0.08916 .
## log(Mean_Temp_lag11)_20 -1.045313   0.137749 -7.5885 1.014e-13 ***
## rho_20                  -0.029948   0.084571 -0.3541   0.72335
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.5201
##   Equation  21
##                          Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_21          21.323134  15.940344  1.3377   0.18143
## log(Density)_21         -0.179568   0.087240 -2.0583   0.03992 *
## Transit_21               0.565511   0.251287  2.2505   0.02472 *
## log(Humidity_lag11)_21  -0.222139   0.243234 -0.9133   0.36141
## log(Mean_Temp_lag11)_21 -1.032693   0.132424 -7.7984 2.229e-14 ***
## rho_21                  -0.039761   0.084148 -0.4725   0.63671
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.5358
##   Equation  22
##                          Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_22          21.852977  15.931097  1.3717   0.17058
## log(Density)_22         -0.191879   0.089151 -2.1523   0.03171 *
## Transit_22               0.572729   0.259671  2.2056   0.02773 *
## log(Humidity_lag11)_22  -0.369273   0.253769 -1.4552   0.14607
## log(Mean_Temp_lag11)_22 -0.996763   0.131245 -7.5947 9.702e-14 ***
## rho_22                  -0.017676   0.087009 -0.2032   0.83907
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.5267
##
## Variance-Covariance Matrix of inter-equation residuals:
##  0.8614692 0.7128763 0.6069753 0.5666740 0.5618446 0.5029521 0.4409424
##  0.7128763 0.6752976 0.5701493 0.5483673 0.5346766 0.4634641 0.4146787
##  0.6069753 0.5701493 0.5410144 0.5200422 0.5079786 0.4327944 0.3872207
##  0.5666740 0.5483673 0.5200422 0.5220324 0.5159519 0.4463163 0.3959960
##  0.5618446 0.5346766 0.5079786 0.5159519 0.5482898 0.4724923 0.4174235
##  0.5029521 0.4634641 0.4327944 0.4463163 0.4724923 0.4707426 0.4134749
##  0.4409424 0.4146787 0.3872207 0.3959960 0.4174235 0.4134749 0.3789324
##  0.4352375 0.4029638 0.3785389 0.3893087 0.4086415 0.4062192 0.3728429
##  0.4151495 0.3827401 0.3583289 0.3679981 0.3856756 0.3822814 0.3536861
##  0.3464757 0.3324815 0.2962419 0.3083590 0.3298425 0.3284442 0.3088738
##  0.3033281 0.2913886 0.2734343 0.2918313 0.3048269 0.3126865 0.2887205
##  0.2873296 0.2766297 0.2603663 0.2806706 0.2877113 0.3063809 0.2817799
##  0.2353946 0.2306874 0.2149653 0.2297813 0.2297847 0.2528627 0.2357616
##  0.2312223 0.2294441 0.2124084 0.2231555 0.2169337 0.2354178 0.2219870
```

```
##  0.2017568 0.2076484 0.1905316 0.1997229 0.1930981 0.2058055 0.1968774
##  0.1922789 0.2057052 0.1906783 0.1964542 0.1922799 0.1977544 0.1921823
##  0.2015118 0.2089944 0.1932205 0.1972908 0.1928276 0.2005995 0.1954184
##  0.1915607 0.2074066 0.1959248 0.1996755 0.1917134 0.1930807 0.1883101
##  0.1876453 0.1961513 0.1981455 0.2084073 0.2010179 0.2057642 0.1934668
##  0.1997775 0.2129457 0.2063476 0.2145318 0.2109836 0.2134275 0.2043284
##  0.1964650 0.2088271 0.2020289 0.2104867 0.2075185 0.2112441 0.2038304
##  0.2029518 0.2185990 0.2139889 0.2230217 0.2197709 0.2233220 0.2152874
##
##  0.4352375 0.4151495 0.3464757 0.3033281 0.2873296 0.2353946 0.2312223
##  0.4029638 0.3827401 0.3324815 0.2913886 0.2766297 0.2306874 0.2294441
##  0.3785389 0.3583289 0.2962419 0.2734343 0.2603663 0.2149653 0.2124084
##  0.3893087 0.3679981 0.3083590 0.2918313 0.2806706 0.2297813 0.2231555
##  0.4086415 0.3856756 0.3298425 0.3048269 0.2877113 0.2297847 0.2169337
##  0.4062192 0.3822814 0.3284442 0.3126865 0.3063809 0.2528627 0.2354178
##  0.3728429 0.3536861 0.3088738 0.2887205 0.2817799 0.2357616 0.2219870
##  0.3803079 0.3624861 0.3166292 0.2968097 0.2908724 0.2453525 0.2315944
##  0.3624861 0.3600664 0.3143770 0.2925381 0.2891872 0.2479110 0.2387854
##  0.3166292 0.3143770 0.3004487 0.2698730 0.2682550 0.2368680 0.2294786
##  0.2968097 0.2925381 0.2698730 0.2615204 0.2637347 0.2351660 0.2282566
##  0.2908724 0.2891872 0.2682550 0.2637347 0.2787569 0.2545150 0.2493687
##  0.2453525 0.2479110 0.2368680 0.2351660 0.2545150 0.2507232 0.2527469
##  0.2315944 0.2387854 0.2294786 0.2282566 0.2493687 0.2527469 0.2647638
##  0.2078900 0.2147489 0.2125818 0.2080885 0.2278939 0.2357054 0.2492875
##  0.2021375 0.2081708 0.2064166 0.1980183 0.2141948 0.2216206 0.2348196
##  0.2065414 0.2112955 0.2051441 0.1958664 0.2115373 0.2159380 0.2276379
##  0.1996976 0.2047244 0.1979831 0.1901192 0.2043830 0.2089238 0.2210993
##  0.2046634 0.2009788 0.1886613 0.1898130 0.2013415 0.1989658 0.2053426
##  0.2149288 0.2166784 0.2059489 0.1999203 0.2127210 0.2080921 0.2159258
##  0.2140472 0.2146036 0.2016206 0.1947717 0.2057023 0.1979237 0.2036191
##  0.2245004 0.2239523 0.2087234 0.2022218 0.2122362 0.2013532 0.2067525
##
##  0.2017568 0.1922789 0.2015118 0.1915607 0.1876453 0.1997775 0.1964650
##  0.2076484 0.2057052 0.2089944 0.2074066 0.1961513 0.2129457 0.2088271
##  0.1905316 0.1906783 0.1932205 0.1959248 0.1981455 0.2063476 0.2020289
##  0.1997229 0.1964542 0.1972908 0.1996755 0.2084073 0.2145318 0.2104867
##  0.1930981 0.1922799 0.1928276 0.1917134 0.2010179 0.2109836 0.2075185
##  0.2058055 0.1977544 0.2005995 0.1930807 0.2057642 0.2134275 0.2112441
##  0.1968774 0.1921823 0.1954184 0.1883101 0.1934668 0.2043284 0.2038304
##  0.2078900 0.2021375 0.2065414 0.1996976 0.2046634 0.2149288 0.2140472
##  0.2147489 0.2081708 0.2112955 0.2047244 0.2009788 0.2166784 0.2146036
##  0.2125818 0.2064166 0.2051441 0.1979831 0.1886613 0.2059489 0.2016206
##  0.2080885 0.1980183 0.1958664 0.1901192 0.1898130 0.1999203 0.1947717
##  0.2278939 0.2141948 0.2115373 0.2043830 0.2013415 0.2127210 0.2057023
##  0.2357054 0.2216206 0.2159380 0.2089238 0.1989658 0.2080921 0.1979237
##  0.2492875 0.2348196 0.2276379 0.2210993 0.2053426 0.2159258 0.2036191
##  0.2480219 0.2383940 0.2295330 0.2274621 0.2099008 0.2190525 0.2062745
##  0.2383940 0.2369062 0.2286525 0.2289572 0.2084965 0.2181815 0.2058295
##  0.2295330 0.2286525 0.2254362 0.2244902 0.2050242 0.2153932 0.2041496
##  0.2274621 0.2289572 0.2244902 0.2297754 0.2123585 0.2203001 0.2087171
##  0.2099008 0.2084965 0.2050242 0.2123585 0.2286917 0.2138130 0.2040403
##  0.2190525 0.2181815 0.2153932 0.2203001 0.2138130 0.2232978 0.2143439
##  0.2062745 0.2058295 0.2041496 0.2087171 0.2040403 0.2143439 0.2087018
##  0.2092018 0.2089101 0.2076080 0.2131338 0.2088699 0.2198852 0.2148381
```

```
##
##  0.2029518
##  0.2185990
##  0.2139889
##  0.2230217
##  0.2197709
##  0.2233220
##  0.2152874
##  0.2245004
##  0.2239523
##  0.2087234
##  0.2022218
##  0.2122362
##  0.2013532
##  0.2067525
##  0.2092018
##  0.2089101
##  0.2076080
##  0.2131338
##  0.2088699
##  0.2198852
##  0.2148381
##  0.2234821
## Correlation Matrix of inter-equation residuals:
##  1.0000000 0.9430030 0.9049832 0.8719173 0.8512014 0.8169560 0.7991182
##  0.9430030 1.0000000 0.9510560 0.9385805 0.9012332 0.8366626 0.8333780
##  0.9049832 0.9510560 1.0000000 0.9815879 0.9410784 0.8790067 0.8746060
##  0.8719173 0.9385805 0.9815879 1.0000000 0.9653513 0.9083406 0.8990475
##  0.8512014 0.9012332 0.9410784 0.9653513 1.0000000 0.9279475 0.9154556
##  0.8169560 0.8366626 0.8790067 0.9083406 0.9279475 1.0000000 0.9813419
##  0.7991182 0.8333780 0.8746060 0.8990475 0.9154556 0.9813419 1.0000000
##  0.7893782 0.8080917 0.8513834 0.8775614 0.8946601 0.9679943 0.9863854
##  0.7840963 0.7997042 0.8323648 0.8585218 0.8789091 0.9500584 0.9711782
##  0.7378075 0.7736698 0.7768609 0.8100699 0.8462299 0.9108511 0.9425054
##  0.7217695 0.7541126 0.7868714 0.8306543 0.8492054 0.9321655 0.9552156
##  0.6716714 0.7102437 0.7486902 0.7973326 0.8068652 0.9076010 0.9300957
##  0.6218792 0.6659386 0.7002150 0.7428847 0.7443144 0.8543834 0.8864404
##  0.6145721 0.6647283 0.6962092 0.7323569 0.7212809 0.8240759 0.8594469
##  0.5897964 0.6459800 0.6724751 0.7087695 0.7012318 0.7942748 0.8351705
##  0.5869115 0.6527704 0.6772607 0.7100762 0.7087759 0.7909261 0.8367230
##  0.6017897 0.6580403 0.6816470 0.7114988 0.7102162 0.8033838 0.8497061
##  0.5800427 0.6508829 0.6805979 0.7078893 0.6988980 0.7782072 0.8251846
##  0.5535065 0.6051779 0.6651563 0.7025234 0.6881953 0.7722652 0.8044308
##  0.5640305 0.6330351 0.6780014 0.7113166 0.7076305 0.7920542 0.8325369
##  0.5678237 0.6339731 0.6801608 0.7135478 0.7093243 0.7953071 0.8404727
##  0.5627169 0.6363476 0.6848031 0.7180724 0.7123107 0.8000835 0.8455359
##
##  0.7893782 0.7840963 0.7378075 0.7217695 0.6716714 0.6218792 0.6145721
##  0.8080917 0.7997042 0.7736698 0.7541126 0.7102437 0.6659386 0.6647283
##  0.8513834 0.8323648 0.7768609 0.7868714 0.7486902 0.7002150 0.6962092
##  0.8775614 0.8585218 0.8100699 0.8306543 0.7973326 0.7428847 0.7323569
##  0.8946601 0.8789091 0.8462299 0.8492054 0.8068652 0.7443144 0.7212809
##  0.9679943 0.9500584 0.9108511 0.9321655 0.9076010 0.8543834 0.8240759
##  0.9863854 0.9711782 0.9425054 0.9552156 0.9300957 0.8864404 0.8594469
```

```
##  1.0000000 0.9864868 0.9565339 0.9697111 0.9466304 0.9039528 0.8758477
##  0.9864868 1.0000000 0.9673851 0.9737169 0.9524355 0.9130373 0.8918443
##  0.9565339 0.9673851 1.0000000 0.9743273 0.9574438 0.9287958 0.9049994
##  0.9697111 0.9737169 0.9743273 1.0000000 0.9858794 0.9596253 0.9387421
##  0.9466304 0.9524355 0.9574438 0.9858794 1.0000000 0.9815471 0.9619468
##  0.9039528 0.9130373 0.9287958 0.9596253 0.9815471 1.0000000 0.9887625
##  0.8758477 0.8918443 0.9049994 0.9387421 0.9619468 0.9887625 1.0000000
##  0.8582535 0.8716038 0.8961646 0.9208684 0.9445574 0.9756508 0.9843713
##  0.8589279 0.8683440 0.8942708 0.9108841 0.9318552 0.9623341 0.9688478
##  0.8745450 0.8809208 0.8989764 0.9156016 0.9386002 0.9648525 0.9693536
##  0.8507731 0.8583203 0.8725629 0.8911892 0.9118408 0.9403827 0.9488897
##  0.8307496 0.8212440 0.8213135 0.8644469 0.8815063 0.9034141 0.9041565
##  0.8560277 0.8627017 0.8713053 0.8971254 0.9207501 0.9387040 0.9441830
##  0.8649980 0.8716068 0.8744545 0.8990498 0.9204352 0.9333632 0.9364158
##  0.8672810 0.8723087 0.8732773 0.8990968 0.9178708 0.9257128 0.9288078
##
##  0.5897964 0.5869115 0.6017897 0.5800427 0.5535065 0.5640305 0.5678237
##  0.6459800 0.6527704 0.6580403 0.6508829 0.6051779 0.6330351 0.6339731
##  0.6724751 0.6772607 0.6816470 0.6805979 0.6651563 0.6780014 0.6801608
##  0.7087695 0.7100762 0.7114988 0.7078893 0.7025234 0.7113166 0.7135478
##  0.7012318 0.7087759 0.7102162 0.6988980 0.6881953 0.7076305 0.7093243
##  0.7942748 0.7909261 0.8033838 0.7782072 0.7722652 0.7920542 0.7953071
##  0.8351705 0.8367230 0.8497061 0.8251846 0.8044308 0.8325369 0.8404727
##  0.8582535 0.8589279 0.8745450 0.8507731 0.8307496 0.8560277 0.8649980
##  0.8716038 0.8683440 0.8809208 0.8583203 0.8212440 0.8627017 0.8716068
##  0.8961646 0.8942708 0.8989764 0.8725629 0.8213135 0.8713053 0.8744545
##  0.9208684 0.9108841 0.9156016 0.8911892 0.8644469 0.8971254 0.8990498
##  0.9445574 0.9318552 0.9386002 0.9118408 0.8815063 0.9207501 0.9204352
##  0.9756508 0.9623341 0.9648525 0.9403827 0.9034141 0.9387040 0.9333632
##  0.9843713 0.9688478 0.9693536 0.9488897 0.9041565 0.9441830 0.9364158
##  1.0000000 0.9939426 0.9901187 0.9799989 0.9338834 0.9723292 0.9646761
##  0.9939426 1.0000000 0.9945538 0.9897416 0.9358011 0.9779544 0.9715683
##  0.9901187 0.9945538 1.0000000 0.9904628 0.9375020 0.9807497 0.9764721
##  0.9799989 0.9897416 0.9904628 1.0000000 0.9502568 0.9911970 0.9861513
##  0.9338834 0.9358011 0.9375020 0.9502568 1.0000000 0.9565452 0.9516558
##  0.9723292 0.9779544 0.9807497 0.9911970 0.9565452 1.0000000 0.9970615
##  0.9646761 0.9715683 0.9764721 0.9861513 0.9516558 0.9970615 1.0000000
##  0.9563003 0.9634739 0.9685386 0.9804105 0.9439070 0.9925708 0.9972330
##
##  0.5627169
##  0.6363476
##  0.6848031
##  0.7180724
##  0.7123107
##  0.8000835
##  0.8455359
##  0.8672810
##  0.8723087
##  0.8732773
##  0.8990968
##  0.9178708
##  0.9257128
##  0.9288078
##  0.9563003
```

```
##  0.9634739
##  0.9685386
##  0.9804105
##  0.9439070
##  0.9925708
##  0.9972330
##  1.0000000
##
##  R-sq. pooled: 0.7811
##  Breusch-Pagan:  7128  p-value: (   0)
```

Model with 11-day weighted moving average of climatic variables:

```
sur.slm_lag11w <- spsur::spsurtime(formula = formula_lag11w,
                                   data=GPanel,
                                   time = GPanel$Date,
                                   type = "slm",
                                   fit_method = "3sls",
                                   listw=  listw,
                                  R = R2,
                                  b = b2)
```

```
## Time to fit the model:  0.33  seconds
```

```
summary(sur.slm_lag11w)
```

```
## Call:
## spsur::spsurtime(formula = formula_lag11w, data = GPanel, time = GPanel$Date,
##     listw = listw, type = "slm", fit_method = "3sls", R = R2,
##     b = b2)
##
##
## Spatial SUR model type:  slm
##
## Equation  1
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)_1           16.728380  17.788987  0.9404   0.3473
## log(Male2Female)_1      -3.019069   2.789941 -1.0821   0.2796
## log(Median_Age)_1       -0.062711   1.489109 -0.0421   0.9664
## log(Density)_1          -0.028375   0.151078 -0.1878   0.8511
## Transit_1                0.532438   0.516574  1.0307   0.3030
## log(Humidity_lag11w)_1   0.088415   0.515708  0.1714   0.8639
## log(Mean_Temp_lag11w)_1 -0.652154   0.515069 -1.2662   0.2059
## rho_1                    0.214902   0.181993  1.1808   0.2381
## R-squared: 0.1638
##   Equation  2
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)_2           19.068767  17.741754  1.0748  0.28283
## log(Density)_2          -0.056934   0.134866 -0.4222  0.67304
## Transit_2                0.598957   0.459089  1.3047  0.19243
## log(Humidity_lag11w)_2  -0.141826   0.467059 -0.3037  0.76148
## log(Mean_Temp_lag11w)_2 -0.890513   0.459480 -1.9381  0.05301 .
## rho_2                    0.079373   0.149481  0.5310  0.59559
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.1678
```

```
##   Equation  3
##                          Estimate Std. Error t value Pr(>|t|)
## (Intercept)_3           19.55491   17.69208  1.1053  0.26941
## log(Density)_3          -0.10817    0.12379 -0.8738  0.38253
## Transit_3                0.62548    0.41462  1.5086  0.13185
## log(Humidity_lag11w)_3  -0.24839    0.40898 -0.6074  0.54381
## log(Mean_Temp_lag11w)_3 -0.80453    0.35969 -2.2368  0.02561 *
## rho_3                    0.19203    0.11826  1.6237  0.10487
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.2046
##   Equation  4
##                          Estimate Std. Error t value Pr(>|t|)
## (Intercept)_4           21.69989   17.68009  1.2274 0.220091
## log(Density)_4          -0.13304    0.12206 -1.0899 0.276113
## Transit_4                0.62672    0.40792  1.5364 0.124888
## log(Humidity_lag11w)_4  -0.63534    0.42046 -1.5111 0.131216
## log(Mean_Temp_lag11w)_4 -0.90386    0.30881 -2.9269 0.003533 **
## rho_4                    0.19466    0.10341  1.8824 0.060187 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.2188
##   Equation  5
##                           Estimate Std. Error t value Pr(>|t|)
## (Intercept)_5           21.783583  17.746896  1.2275 0.220055
## log(Density)_5          -0.167873   0.124676 -1.3465 0.178578
## Transit_5                0.644501   0.418924  1.5385 0.124378
## log(Humidity_lag11w)_5  -0.679094   0.522884 -1.2987 0.194451
## log(Mean_Temp_lag11w)_5 -0.802037   0.308059 -2.6035 0.009419 **
## rho_5                    0.261210   0.099134  2.6349 0.008599 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.2061
##   Equation  6
##                          Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_6           21.76425   17.65648  1.2326 0.2181128
## log(Density)_6          -0.12650    0.12071 -1.0479 0.2950345
## Transit_6                0.55003    0.39855  1.3801 0.1679905
## log(Humidity_lag11w)_6  -0.27528    0.42593 -0.6463 0.5182824
## log(Mean_Temp_lag11w)_6 -0.91486    0.25360 -3.6075 0.0003307 ***
## rho_6                   -0.18120    0.11073 -1.6364 0.1021876
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.1589
##   Equation  7
##                           Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_7           19.813606  17.583049  1.1269    0.2602
## log(Density)_7          -0.155352   0.109158 -1.4232    0.1551
## Transit_7                0.478134   0.344999  1.3859    0.1662
## log(Humidity_lag11w)_7   0.172913   0.309239  0.5592    0.5762
## log(Mean_Temp_lag11w)_7 -0.967007   0.206635 -4.6798 3.437e-06 ***
## rho_7                   -0.030009   0.103904 -0.2888    0.7728
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
## R-squared: 0.277
##   Equation  8
##                            Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_8           21.124547  17.581243  1.2015    0.2299
## log(Density)_8          -0.145061   0.105603 -1.3736    0.1700
## Transit_8                0.443452   0.327007  1.3561    0.1755
## log(Humidity_lag11w)_8   0.021279   0.248750  0.0855    0.9319
## log(Mean_Temp_lag11w)_8 -1.289341   0.198137 -6.5073 1.441e-10 ***
## rho_8                    0.052057   0.094463  0.5511    0.5818
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.3769
##   Equation  9
##                            Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_9           22.654093  17.620638  1.2857    0.1990
## log(Density)_9          -0.085518   0.101805 -0.8400    0.4012
## Transit_9                0.375669   0.306142  1.2271    0.2202
## log(Humidity_lag11w)_9  -0.276233   0.268408 -1.0292    0.3038
## log(Mean_Temp_lag11w)_9 -1.441504   0.214997 -6.7048 4.105e-11 ***
## rho_9                    0.054898   0.098158  0.5593    0.5761
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.4015
##   Equation  10
##                             Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_10           24.210165  17.681524  1.3692    0.1714
## log(Density)_10          -0.043610   0.095878 -0.4548    0.6494
## Transit_10                0.363157   0.274124  1.3248    0.1857
## log(Humidity_lag11w)_10  -0.443696   0.311341 -1.4251    0.1546
## log(Mean_Temp_lag11w)_10 -1.709520   0.233991 -7.3059 7.392e-13 ***
## rho_10                    0.025206   0.095585  0.2637    0.7921
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.5029
##   Equation  11
##                             Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_11           23.664674  17.680189  1.3385    0.1812
## log(Density)_11          -0.059212   0.092242 -0.6419    0.5211
## Transit_11                0.341825   0.257473  1.3276    0.1847
## log(Humidity_lag11w)_11  -0.283007   0.274899 -1.0295    0.3036
## log(Mean_Temp_lag11w)_11 -1.725103   0.212057 -8.1351 1.828e-15 ***
## rho_11                    0.065952   0.084701  0.7786    0.4364
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.5335
##   Equation  12
##                             Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_12           25.518736  17.653354  1.4455   0.14874
## log(Density)_12          -0.044945   0.096776 -0.4644   0.64249
## Transit_12                0.383706   0.275264  1.3940   0.16376
## log(Humidity_lag11w)_12  -0.642175   0.298322 -2.1526   0.03168 *
## log(Mean_Temp_lag11w)_12 -1.741662   0.226562 -7.6874 4.988e-14 ***
## rho_12                    0.030963   0.085447  0.3624   0.71719
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.5022
##   Equation  13
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)_13           23.567226  17.686725  1.3325   0.1831
## log(Density)_13          -0.056782   0.100110 -0.5672   0.5708
## Transit_13                0.401034   0.285850  1.4029   0.1611
## log(Humidity_lag11w)_13  -0.275563   0.357180 -0.7715   0.4407
## log(Mean_Temp_lag11w)_13 -1.663638   0.262090 -6.3476 3.89e-10 ***
## rho_13                    0.107812   0.090469  1.1917   0.2338
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.4718
##   Equation  14
##                            Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_14           22.616437  17.659057  1.2807    0.2007
## log(Density)_14          -0.073981   0.103093 -0.7176    0.4732
## Transit_14                0.435735   0.298929  1.4577    0.1454
## log(Humidity_lag11w)_14  -0.129900   0.376371 -0.3451    0.7301
## log(Mean_Temp_lag11w)_14 -1.471458   0.274804 -5.3546 1.158e-07 ***
## rho_14                    0.108230   0.089208  1.2132    0.2254
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.4196
##   Equation  15
##                            Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_15           25.027427  17.626882  1.4198   0.15609
## log(Density)_15          -0.136023   0.098117 -1.3863   0.16608
## Transit_15                0.476728   0.281457  1.6938   0.09074 .
## log(Humidity_lag11w)_15  -0.646091   0.319381 -2.0230   0.04345 *
## log(Mean_Temp_lag11w)_15 -1.442830   0.231845 -6.2232 8.305e-10 ***
## rho_15                    0.143536   0.078644  1.8251   0.06840 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared:  0.47
##   Equation  16
##                            Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_16           24.359527  17.593904  1.3845   0.16663
## log(Density)_16          -0.167473   0.095911 -1.7461   0.08122 .
## Transit_16                0.466947   0.275516  1.6948   0.09055 .
## log(Humidity_lag11w)_16  -0.596686   0.280196 -2.1295   0.03355 *
## log(Mean_Temp_lag11w)_16 -1.195593   0.184090 -6.4946 1.561e-10 ***
## rho_16                    0.147230   0.077930  1.8893   0.05926 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.4703
##   Equation  17
##                            Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_17           24.605163  17.585514  1.3992  0.162196
## log(Density)_17          -0.180037   0.093947 -1.9164  0.055717 .
## Transit_17                0.518065   0.268749  1.9277  0.054290 .
## log(Humidity_lag11w)_17  -0.656768   0.238751 -2.7508  0.006095 **
## log(Mean_Temp_lag11w)_17 -0.989445   0.144968 -6.8252 1.878e-11 ***
## rho_17                    0.061718   0.078737  0.7838  0.433390
```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.4705
##   Equation  18
##                             Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_18           24.6308426 17.5852038  1.4007   0.16175
## log(Density)_18          -0.1821645  0.0927047 -1.9650   0.04980 *
## Transit_18                0.5116254  0.2631761  1.9440   0.05228 .
## log(Humidity_lag11w)_18  -0.6080792  0.2220235 -2.7388   0.00632 **
## log(Mean_Temp_lag11w)_18 -0.9406689  0.1319387 -7.1296 2.474e-12 ***
## rho_18                    0.0006495  0.0839231  0.0077   0.99383
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.4985
##   Equation  19
##                             Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_19           22.280458  17.645544  1.2627   0.20712
## log(Density)_19          -0.168643   0.092785 -1.8176   0.06955 .
## Transit_19                0.253597   0.264875  0.9574   0.33868
## log(Humidity_lag11w)_19  -0.051032   0.305788 -0.1669   0.86751
## log(Mean_Temp_lag11w)_19 -0.964398   0.147664 -6.5311 1.242e-10 ***
## rho_19                    0.010844   0.106846  0.1015   0.91919
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.4799
##   Equation  20
##                             Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_20           23.779849  17.580085  1.3527   0.17659
## log(Density)_20          -0.189367   0.091374 -2.0724   0.03858 *
## Transit_20                0.544434   0.257922  2.1108   0.03513 *
## log(Humidity_lag11w)_20  -0.327215   0.213344 -1.5337   0.12554
## log(Mean_Temp_lag11w)_20 -0.852376   0.110807 -7.6925 4.808e-14 ***
## rho_20                   -0.075817   0.087780 -0.8637   0.38804
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.5169
##   Equation  21
##                             Estimate Std. Error t value  Pr(>|t|)
## (Intercept)_21           22.595275  17.566118  1.2863   0.19876
## log(Density)_21          -0.204157   0.090874 -2.2466   0.02497 *
## Transit_21                0.562833   0.255601  2.2020   0.02799 *
## log(Humidity_lag11w)_21  -0.060156   0.231143 -0.2603   0.79474
## log(Mean_Temp_lag11w)_21 -0.732097   0.100380 -7.2933 8.069e-13 ***
## rho_21                   -0.097945   0.091639 -1.0688   0.28551
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.512
##   Equation  22
##                             Estimate Std. Error t value Pr(>|t|)
## (Intercept)_22           22.892552  17.562886  1.3035  0.19284
## log(Density)_22          -0.210641   0.092700 -2.2723  0.02337 *
## Transit_22                0.566111   0.263408  2.1492  0.03196 *
## log(Humidity_lag11w)_22  -0.147064   0.286269 -0.5137  0.60760
## log(Mean_Temp_lag11w)_22 -0.725850   0.106521 -6.8141 2.02e-11 ***
```

```
## rho_22                   -0.070910   0.096392 -0.7356  0.46219
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## R-squared: 0.5059
##
## Variance-Covariance Matrix of inter-equation residuals:
##  0.8927437 0.7453608 0.6313726 0.5756197 0.5646415 0.5309016 0.4417635
##  0.7453608 0.7074245 0.6011818 0.5694344 0.5556707 0.4993093 0.4162836
##  0.6313726 0.6011818 0.5775108 0.5541383 0.5453799 0.4812256 0.4013066
##  0.5756197 0.5694344 0.5541383 0.5582397 0.5554138 0.4921260 0.4082892
##  0.5646415 0.5556707 0.5453799 0.5554138 0.5891383 0.5173022 0.4267508
##  0.5309016 0.4993093 0.4812256 0.4921260 0.5173022 0.5333588 0.4465119
##  0.4417635 0.4162836 0.4013066 0.4082892 0.4267508 0.4465119 0.3954939
##  0.4042663 0.3720513 0.3634836 0.3727368 0.3859224 0.4046053 0.3634648
##  0.3684896 0.3372121 0.3257983 0.3326532 0.3423013 0.3532018 0.3193656
##  0.2786769 0.2703905 0.2463396 0.2550389 0.2653230 0.2675129 0.2484124
##  0.2446535 0.2388118 0.2272827 0.2390168 0.2421794 0.2453158 0.2276993
##  0.2240750 0.2259842 0.2179691 0.2346390 0.2330920 0.2416556 0.2240755
##  0.1888998 0.1979965 0.1927072 0.2107614 0.2065696 0.2216870 0.2050520
##  0.2071965 0.2170062 0.2126156 0.2280105 0.2215124 0.2343713 0.2156219
##  0.2083828 0.2179746 0.2115392 0.2225186 0.2196258 0.2231011 0.2066697
##  0.2334906 0.2445005 0.2358158 0.2410083 0.2412994 0.2382779 0.2214933
##  0.2443389 0.2509218 0.2409056 0.2452491 0.2457409 0.2461054 0.2283873
##  0.2261569 0.2373523 0.2335110 0.2390400 0.2375239 0.2295820 0.2131110
##  0.2005076 0.2075122 0.2204874 0.2363005 0.2345743 0.2323624 0.2100681
##  0.2012289 0.2138866 0.2186672 0.2325571 0.2331895 0.2315810 0.2115665
##  0.2011879 0.2137523 0.2174036 0.2325575 0.2349091 0.2376000 0.2185559
##  0.2013762 0.2196559 0.2233163 0.2404392 0.2437452 0.2490568 0.2290291
##
##  0.4042663 0.3684896 0.2786769 0.2446535 0.2240750 0.1888998 0.2071965
##  0.3720513 0.3372121 0.2703905 0.2388118 0.2259842 0.1979965 0.2170062
##  0.3634836 0.3257983 0.2463396 0.2272827 0.2179691 0.1927072 0.2126156
##  0.3727368 0.3326532 0.2550389 0.2390168 0.2346390 0.2107614 0.2280105
##  0.3859224 0.3423013 0.2653230 0.2421794 0.2330920 0.2065696 0.2215124
##  0.4046053 0.3532018 0.2675129 0.2453158 0.2416556 0.2216870 0.2343713
##  0.3634648 0.3193656 0.2484124 0.2276993 0.2240755 0.2050520 0.2156219
##  0.3544475 0.3194422 0.2536257 0.2336836 0.2330611 0.2136797 0.2215817
##  0.3194422 0.3105138 0.2565573 0.2376209 0.2399003 0.2226972 0.2300244
##  0.2536257 0.2565573 0.2475223 0.2230725 0.2298291 0.2196196 0.2224197
##  0.2336836 0.2376209 0.2230725 0.2172384 0.2256986 0.2205552 0.2247579
##  0.2330611 0.2399003 0.2298291 0.2256986 0.2487887 0.2505859 0.2544609
##  0.2136797 0.2226972 0.2196196 0.2205552 0.2505859 0.2680470 0.2758977
##  0.2215817 0.2300244 0.2224197 0.2247579 0.2544609 0.2758977 0.2948114
##  0.2121319 0.2159993 0.2120172 0.2100933 0.2350696 0.2521320 0.2701339
##  0.2239204 0.2202759 0.2092454 0.2015223 0.2200342 0.2298104 0.2484133
##  0.2312834 0.2223571 0.2031275 0.1930734 0.2088103 0.2136783 0.2314531
##  0.2171525 0.2102927 0.1906233 0.1838241 0.2001771 0.2052832 0.2231702
##  0.2137131 0.1965188 0.1673219 0.1658386 0.1823639 0.1874818 0.2035702
##  0.2150977 0.2054377 0.1808974 0.1764188 0.1944809 0.1966666 0.2118370
##  0.2196547 0.2063839 0.1796517 0.1738201 0.1884625 0.1879460 0.2007421
##  0.2276122 0.2118195 0.1831301 0.1771437 0.1897658 0.1876624 0.1995925
##
##  0.2083828 0.2334906 0.2443389 0.2261569 0.2005076 0.2012289 0.2011879
##  0.2179746 0.2445005 0.2509218 0.2373523 0.2075122 0.2138866 0.2137523
```

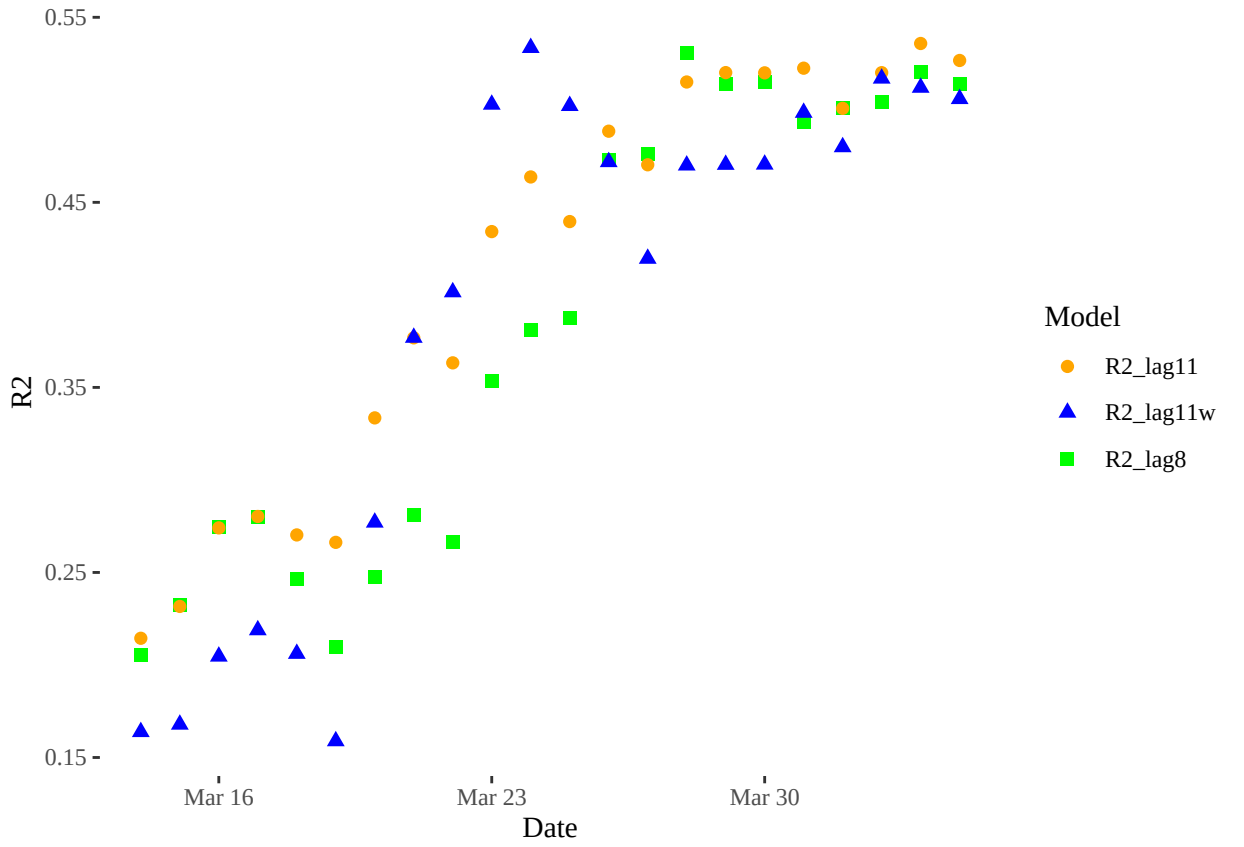
```
##  0.2115392 0.2358158 0.2409056 0.2335110 0.2204874 0.2186672 0.2174036
##  0.2225186 0.2410083 0.2452491 0.2390400 0.2363005 0.2325571 0.2325575
##  0.2196258 0.2412994 0.2457409 0.2375239 0.2345743 0.2331895 0.2349091
##  0.2231011 0.2382779 0.2461054 0.2295820 0.2323624 0.2315810 0.2376000
##  0.2066697 0.2214933 0.2283873 0.2131110 0.2100681 0.2115665 0.2185559
##  0.2121319 0.2239204 0.2312834 0.2171525 0.2137131 0.2150977 0.2196547
##  0.2159993 0.2202759 0.2223571 0.2102927 0.1965188 0.2054377 0.2063839
##  0.2120172 0.2092454 0.2031275 0.1906233 0.1673219 0.1808974 0.1796517
##  0.2100933 0.2015223 0.1930734 0.1838241 0.1658386 0.1764188 0.1738201
##  0.2350696 0.2200342 0.2088103 0.2001771 0.1823639 0.1944809 0.1884625
##  0.2521320 0.2298104 0.2136783 0.2052832 0.1874818 0.1966666 0.1879460
##  0.2701339 0.2484133 0.2314531 0.2231702 0.2035702 0.2118370 0.2007421
##  0.2620231 0.2497462 0.2335918 0.2261872 0.2055578 0.2109494 0.2009553
##  0.2497462 0.2516877 0.2412847 0.2334246 0.2090864 0.2149818 0.2066518
##  0.2335918 0.2412847 0.2393564 0.2312229 0.2099686 0.2164932 0.2095903
##  0.2261872 0.2334246 0.2312229 0.2291605 0.2115229 0.2168979 0.2091202
##  0.2055578 0.2090864 0.2099686 0.2115229 0.2310155 0.2134542 0.2083261
##  0.2109494 0.2149818 0.2164932 0.2168979 0.2134542 0.2197531 0.2148962
##  0.2009553 0.2066518 0.2095903 0.2091202 0.2083261 0.2148962 0.2153475
##  0.2005399 0.2072216 0.2101849 0.2095859 0.2088257 0.2164212 0.2199801
##
##  0.2013762
##  0.2196559
##  0.2233163
##  0.2404392
##  0.2437452
##  0.2490568
##  0.2290291
##  0.2276122
##  0.2118195
##  0.1831301
##  0.1771437
##  0.1897658
##  0.1876624
##  0.1995925
##  0.2005399
##  0.2072216
##  0.2101849
##  0.2095859
##  0.2088257
##  0.2164212
##  0.2199801
##  0.2286234
## Correlation Matrix of inter-equation residuals:
##  1.0000000 0.9473598 0.9098744 0.8736509 0.8543728 0.8228892 0.8036276
##  0.9473598 1.0000000 0.9533383 0.9374810 0.9038103 0.8480396 0.8378633
##  0.9098744 0.9533383 1.0000000 0.9814426 0.9457591 0.8900146 0.8812066
##  0.8736509 0.9374810 0.9814426 1.0000000 0.9683259 0.9178349 0.9065464
##  0.8543728 0.9038103 0.9457591 0.9683259 1.0000000 0.9325522 0.9175634
##  0.8228892 0.8480396 0.8900146 0.9178349 0.9325522 1.0000000 0.9825895
##  0.8036276 0.8378633 0.8812066 0.9065464 0.9175634 0.9825895 1.0000000
##  0.7857977 0.8001925 0.8518265 0.8805656 0.8918122 0.9634858 0.9846395
##  0.7791766 0.7897770 0.8327875 0.8601623 0.8748995 0.9401502 0.9649572
##  0.7266990 0.7523134 0.7650812 0.7989134 0.8328574 0.8850023 0.9232336
```

```
##  0.7223187 0.7457470 0.7815193 0.8216816 0.8384919 0.9038967 0.9386457
##  0.6623700 0.6949270 0.7377847 0.7860912 0.7964389 0.8734295 0.9109194
##  0.6089423 0.6458214 0.6843245 0.7289284 0.7343958 0.8257423 0.8687411
##  0.6161194 0.6584984 0.6959519 0.7342099 0.7294403 0.8205802 0.8623307
##  0.6185728 0.6594449 0.6921020 0.7282764 0.7329507 0.8169280 0.8599039
##  0.6321357 0.6807145 0.7134905 0.7459850 0.7568225 0.8320288 0.8761660
##  0.6449087 0.6875469 0.7210020 0.7513856 0.7620527 0.8474266 0.8912472
##  0.6262334 0.6767567 0.7189331 0.7484641 0.7526831 0.8256275 0.8695084
##  0.5790850 0.6122010 0.6845936 0.7278335 0.7254109 0.7984707 0.8310805
##  0.5860094 0.6366264 0.6950294 0.7344377 0.7413322 0.8180322 0.8580163
##  0.5888401 0.6387031 0.6971759 0.7376204 0.7453950 0.8233201 0.8665804
##  0.5817734 0.6411642 0.6977503 0.7398304 0.7458928 0.8266917 0.8705208
##
##  0.7857977 0.7791766 0.7266990 0.7223187 0.6623700 0.6089423 0.6161194
##  0.8001925 0.7897770 0.7523134 0.7457470 0.6949270 0.6458214 0.6584984
##  0.8518265 0.8327875 0.7650812 0.7815193 0.7377847 0.6843245 0.6959519
##  0.8805656 0.8601623 0.7989134 0.8216816 0.7860912 0.7289284 0.7342099
##  0.8918122 0.8748995 0.8328574 0.8384919 0.7964389 0.7343958 0.7294403
##  0.9634858 0.9401502 0.8850023 0.9038967 0.8734295 0.8257423 0.8205802
##  0.9846395 0.9649572 0.9232336 0.9386457 0.9109194 0.8687411 0.8623307
##  1.0000000 0.9840249 0.9425222 0.9591005 0.9374602 0.8949778 0.8853306
##  0.9840249 1.0000000 0.9610778 0.9727039 0.9521288 0.9112154 0.9028013
##  0.9425222 0.9610778 1.0000000 0.9756744 0.9613886 0.9312980 0.9135825
##  0.9591005 0.9727039 0.9756744 1.0000000 0.9841049 0.9593742 0.9474314
##  0.9374602 0.9521288 0.9613886 0.9841049 1.0000000 0.9836443 0.9686045
##  0.8949778 0.9112154 0.9312980 0.9593742 0.9836443 1.0000000 0.9888401
##  0.8853306 0.9028013 0.9135825 0.9474314 0.9686045 0.9888401 1.0000000
##  0.8874087 0.8985664 0.9190554 0.9442289 0.9637882 0.9812075 0.9863419
##  0.9002557 0.9043224 0.9202499 0.9386828 0.9544880 0.9658761 0.9709623
##  0.9167095 0.9147998 0.9192170 0.9371441 0.9527354 0.9580761 0.9637089
##  0.8965477 0.8969985 0.8964145 0.9195889 0.9355258 0.9422462 0.9508833
##  0.8609842 0.8420222 0.8246611 0.8666842 0.8858243 0.8932841 0.8988690
##  0.8847214 0.8841023 0.8758885 0.9077327 0.9312465 0.9321470 0.9394859
##  0.8916165 0.8886793 0.8768946 0.9079586 0.9272287 0.9238409 0.9287710
##  0.8922926 0.8869168 0.8744277 0.9056714 0.9214639 0.9155268 0.9198895
##
##  0.6185728 0.6321357 0.6449087 0.6262334 0.5790850 0.5860094 0.5888401
##  0.6594449 0.6807145 0.6875469 0.6767567 0.6122010 0.6366264 0.6387031
##  0.6921020 0.7134905 0.7210020 0.7189331 0.6845936 0.6950294 0.6971759
##  0.7282764 0.7459850 0.7513856 0.7484641 0.7278335 0.7344377 0.7376204
##  0.7329507 0.7568225 0.7620527 0.7526831 0.7254109 0.7413322 0.7453950
##  0.8169280 0.8320288 0.8474266 0.8256275 0.7984707 0.8180322 0.8233201
##  0.8599039 0.8761660 0.8912472 0.8695084 0.8310805 0.8580163 0.8665804
##  0.8874087 0.9002557 0.9167095 0.8965477 0.8609842 0.8847214 0.8916165
##  0.8985664 0.9043224 0.9147998 0.8969985 0.8420222 0.8841023 0.8886793
##  0.9190554 0.9202499 0.9192170 0.8964145 0.8246611 0.8758885 0.8768946
##  0.9442289 0.9386828 0.9371441 0.9195889 0.8666842 0.9077327 0.9079586
##  0.9637882 0.9544880 0.9527354 0.9355258 0.8858243 0.9312465 0.9272287
##  0.9812075 0.9658761 0.9580761 0.9422462 0.8932841 0.9321470 0.9238409
##  0.9863419 0.9709623 0.9637089 0.9508833 0.8988690 0.9394859 0.9287710
##  1.0000000 0.9934652 0.9837360 0.9761185 0.9242610 0.9619033 0.9537397
##  0.9934652 1.0000000 0.9932819 0.9884190 0.9298329 0.9707903 0.9650698
##  0.9837360 0.9932819 1.0000000 0.9915241 0.9355559 0.9771097 0.9732811
##  0.9761185 0.9884190 0.9915241 1.0000000 0.9477901 0.9890668 0.9840052
```

```
##  0.9242610 0.9298329 0.9355559 0.9477901 1.0000000 0.9571487 0.9530803
##  0.9619033 0.9707903 0.9771097 0.9890668 0.9571487 1.0000000 0.9964005
##  0.9537397 0.9650698 0.9732811 0.9840052 0.9530803 0.9964005 1.0000000
##  0.9464455 0.9591337 0.9664502 0.9774384 0.9432909 0.9894327 0.9965952
##
##  0.5817734
##  0.6411642
##  0.6977503
##  0.7398304
##  0.7458928
##  0.8266917
##  0.8705208
##  0.8922926
##  0.8869168
##  0.8744277
##  0.9056714
##  0.9214639
##  0.9155268
##  0.9198895
##  0.9464455
##  0.9591337
##  0.9664502
##  0.9774384
##  0.9432909
##  0.9894327
##  0.9965952
##  1.0000000
##
##  R-sq. pooled: 0.7726
##  Breusch-Pagan:  6849  p-value: (   0)
```

Compare goodness of fit:

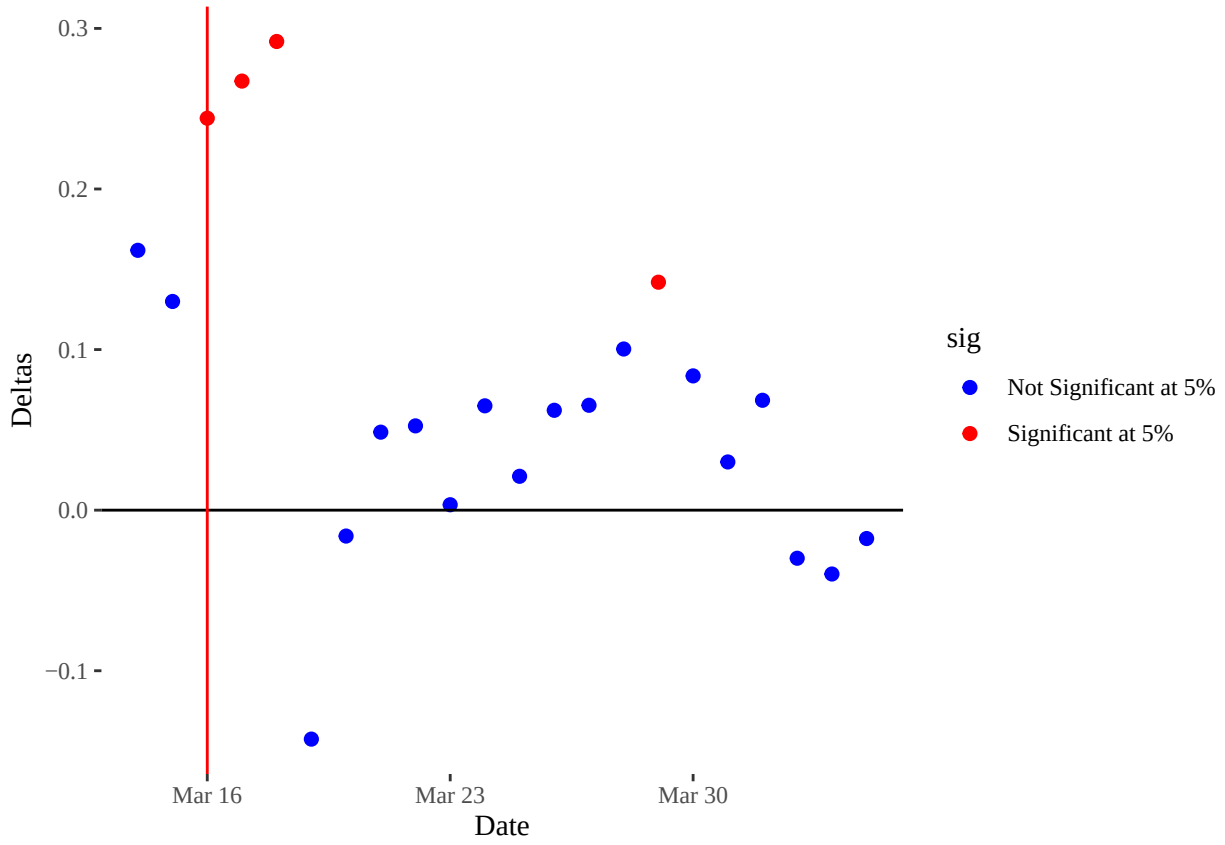
```
data.frame(R2_lag8 = sur.slm_lag8$R2,
           R2_lag11 = sur.slm_lag11$R2,
           R2_lag11w = sur.slm_lag11w$R2) %>%
  slice(2:n()) %>%
  rownames_to_column(var = "Equation") %>%
  mutate(Date = seq(ymd("2020-03-14"),
                    ymd("2020-04-04"),
                    by = "days")) %>%
  pivot_longer(cols = starts_with("R"), names_to = "Model", values_to = "R2") %>%
  ggplot(aes(x = Date, y = R2, color = Model, shape = Model)) +
  geom_point(size = 2) +
  scale_color_manual(values = c("R2_lag11w" = "blue", "R2_lag11" = "orange", "R2_lag8" = "green") ) +
  theme_tufte()
```



Spatial evolution of spatial residual autocorrelation

Plot the evolution of the spatial autocorrelation parameter:

```
data.frame(Date = seq(ymd("2020-03-14"),
                      ymd("2020-04-04"),
                      by = "days"),
           Deltas = sur.slm_lag11$deltas,
           tvalue = sur.slm_lag11$deltas/sur.slm_lag11$deltas.se) %>%
  mutate(sig = ifelse(abs(tvalue) > 1.64, "Significant at 5%", "Not Significant at 5%")) %>%
  ggplot(aes(x = Date, y = Deltas, color = sig)) +
  geom_point(size = 2) +
  scale_color_manual(values = c("Significant at 5%" = "red", "Not Significant at 5%" = "blue")) +
  geom_hline(yintercept = 0) +
  geom_vline(xintercept = as_date("2020-03-16"), color = "red") +
  theme_tufte()
```



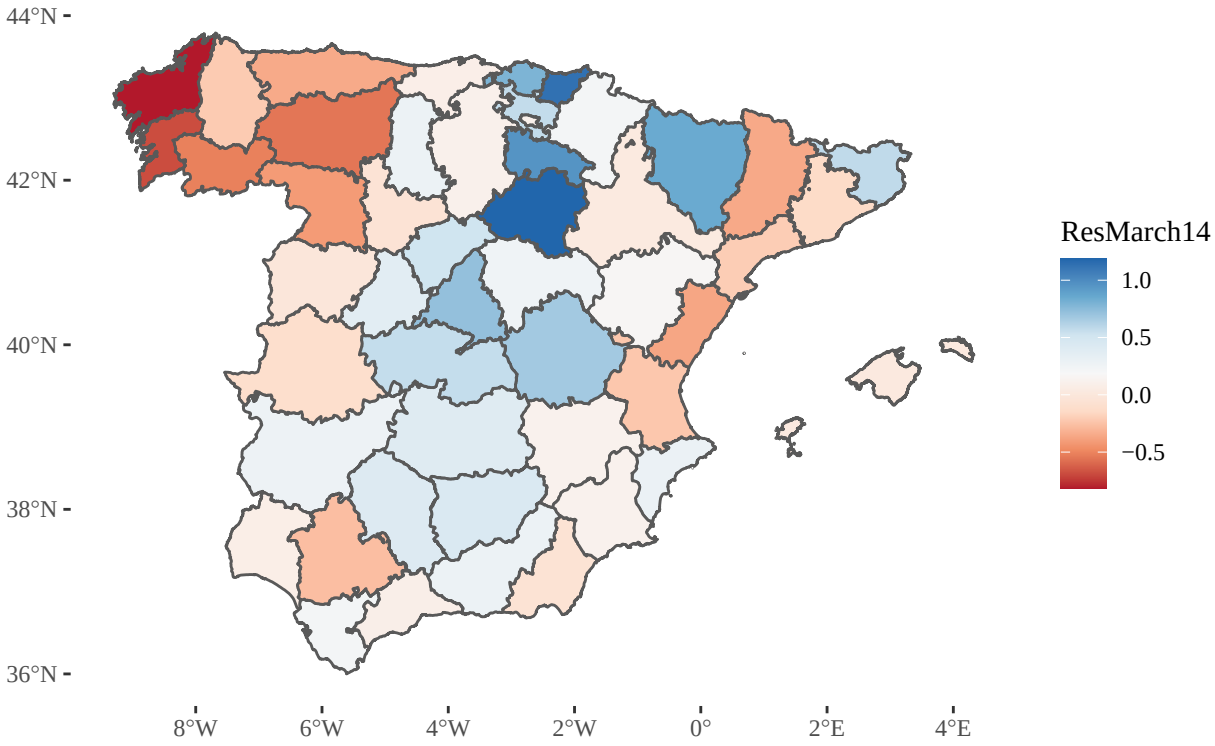
Analisis of autocorrelated residuals

Extract residuals for March 14 and April 2, and compute autocorrelated residuals:

```
residuals_Mar14 <- as.matrix(residuals(sur.slm_lag11w))[[1]]
residuals_Mar14 <- lag.listw(listw, residuals_Mar14)

residuals_Apr04 <- as.matrix(residuals(sur.slm_lag11w))[[22]]
residuals_Apr04 <- lag.listw(listw, residuals_Apr04)
```

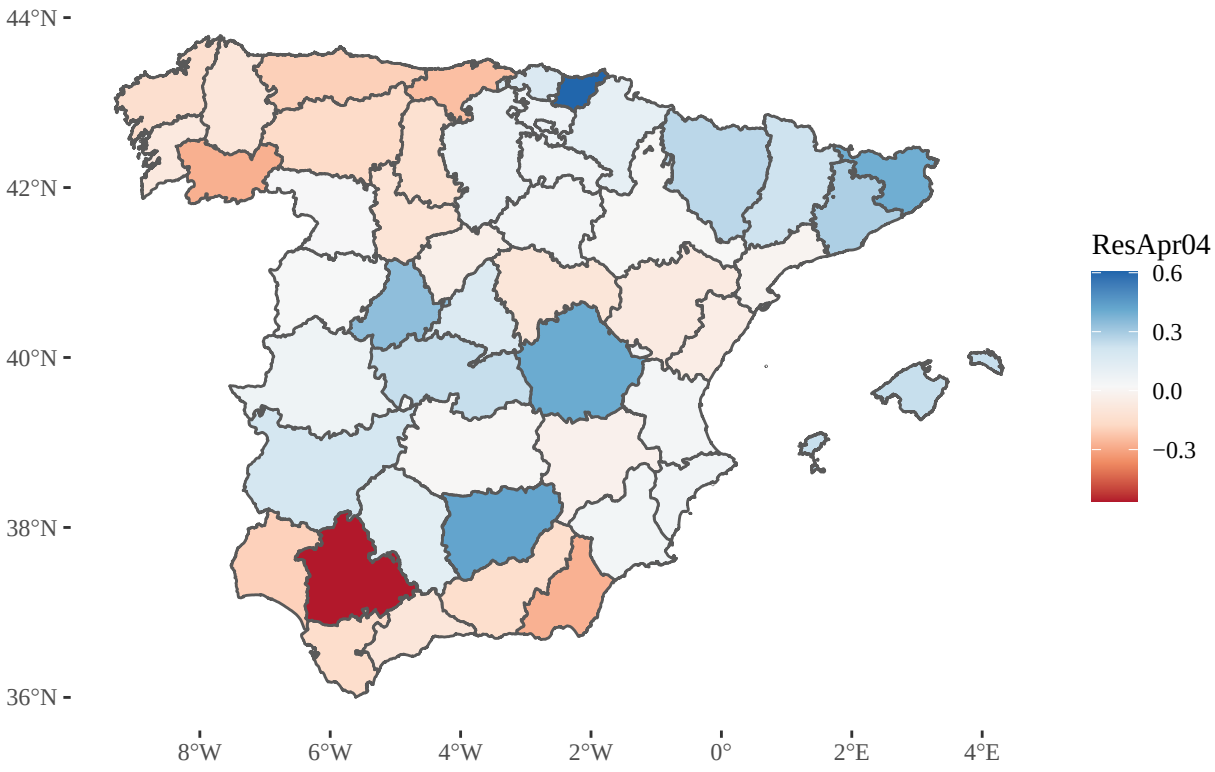
Plot residuals on March 14 (positive autocorrelation):

```
covid19_spain %>% filter(Date == "2020-03-14") %>%
  mutate(ResMarch14 = residuals_Mar14) %>%
  filter(CCAA != "Canarias") %>%
  ggplot() +
  geom_sf(aes(fill = ResMarch14)) +
  scale_fill_distiller(palette = "RdBu", direction = 1) +
  theme_tufte()
```



Plot residuals on April 4:

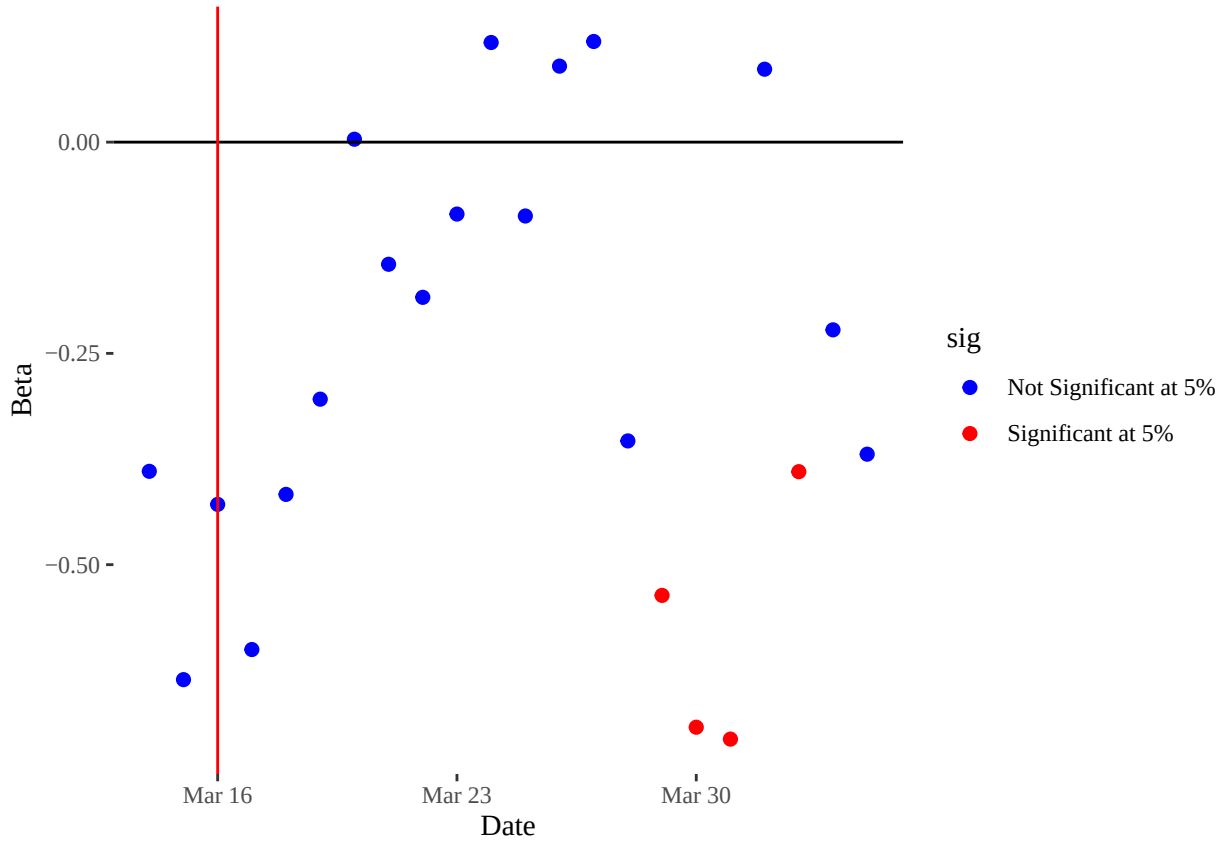
```
covid19_spain %>% filter(Date == "2020-03-14") %>%
  mutate(ResApr04 = residuals_Apr04) %>%
  filter(CCAA != "Canarias") %>%
  ggplot() +
  geom_sf(aes(fill = ResApr04)) +
  scale_fill_distiller(palette = "RdBu", direction = 1) +
  theme_tufte()
```



Temporal variation of coefficients of climatic variables

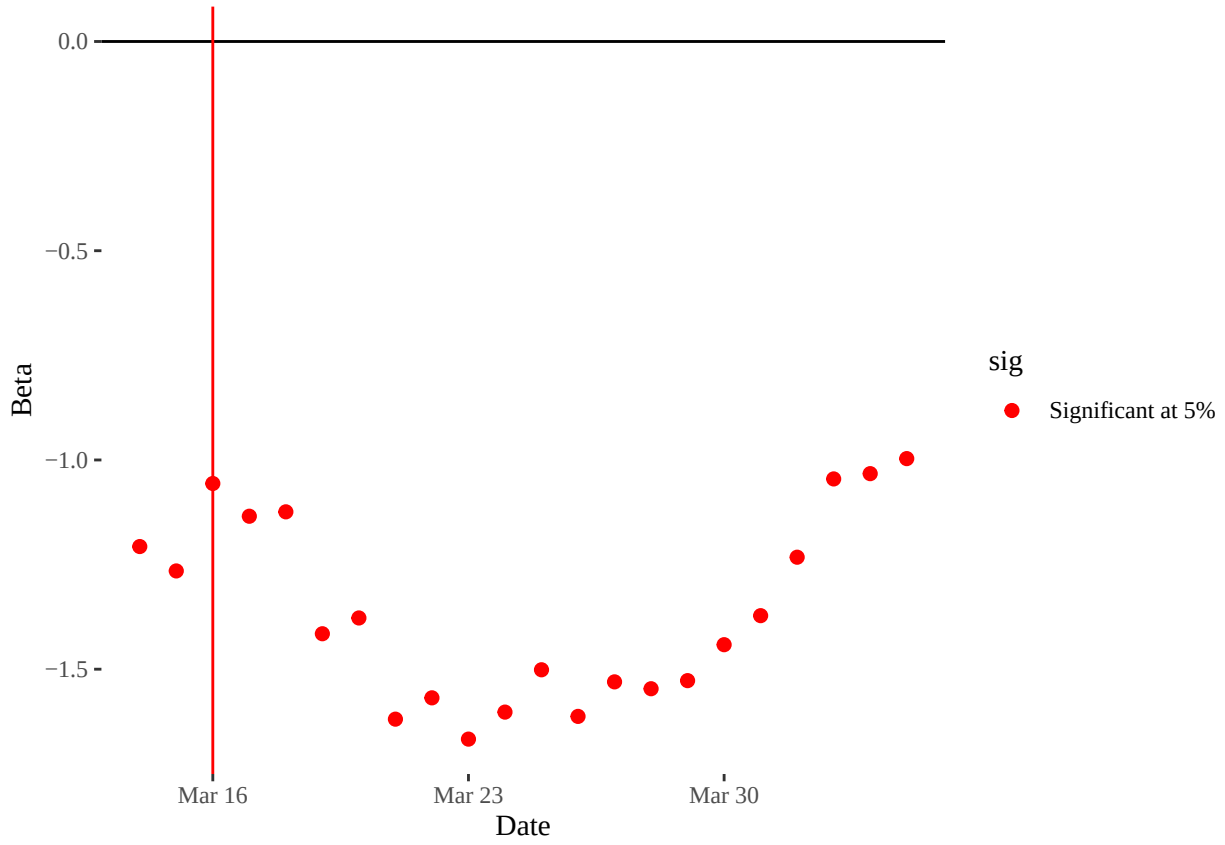
Humidity:

```
n = 4
data.frame(Date = seq(ymd("2020-03-14"),
                      ymd("2020-04-04"),
                      by = "days"),
           Beta = matrix(sur.slm_lag11$coefficients[-c(2,3)],ncol = 22)[n,],
           tvalue = matrix(sur.slm_lag11$coefficients[-c(2,3)]/sur.slm_lag11$rest.se[-c(2,3)], ncol = 2
  mutate(sig = ifelse(abs(tvalue) > 1.64, "Significant at 5%", "Not Significant at 5%")) %>%
  ggplot(aes(x = Date, y = Beta, color = sig)) +
  geom_point(size = 2) +
  scale_color_manual(values = c("Significant at 5%" = "red", "Not Significant at 5%" = "blue")) +
  geom_hline(yintercept = 0) +
  geom_vline(xintercept = as_date("2020-03-16"), color = "red") +
  theme_tufte()
```



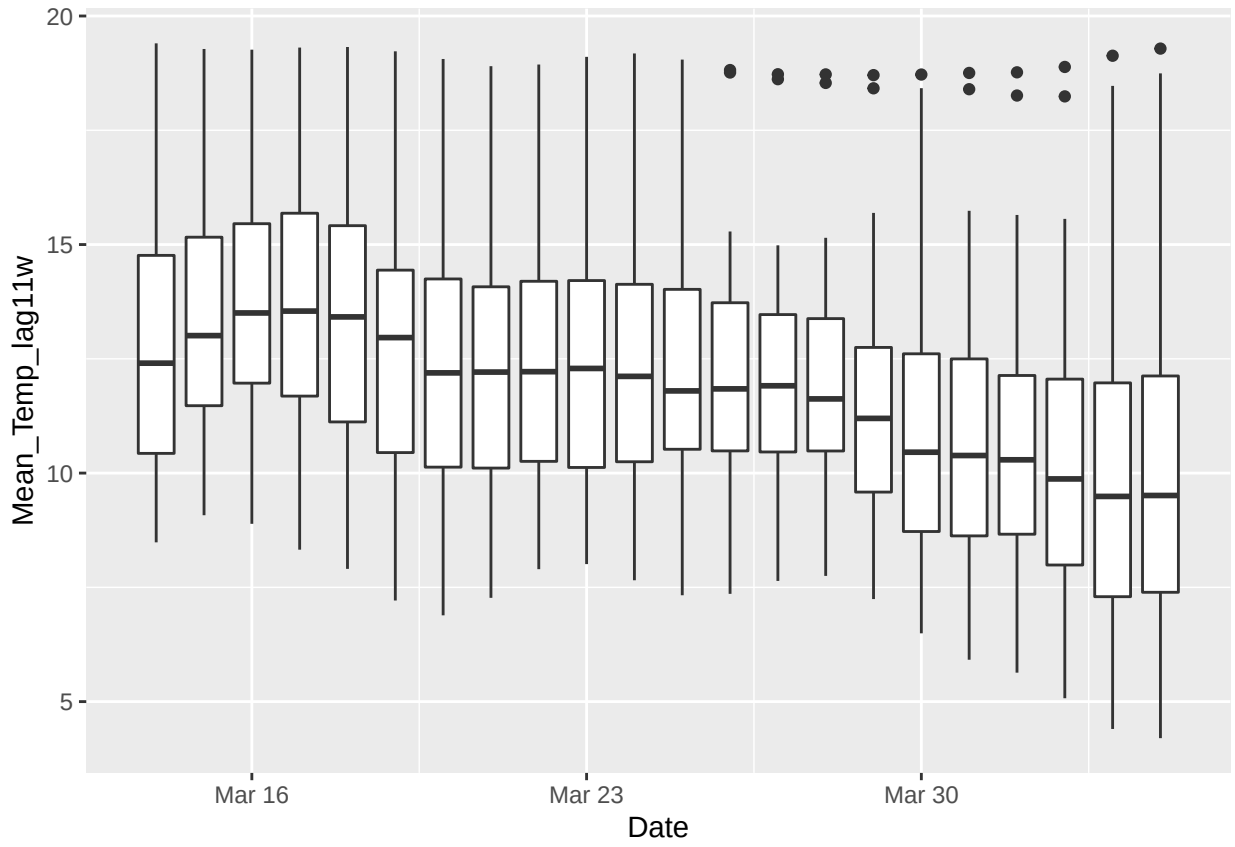
Temperature:

```
n = 5
data.frame(Date = seq(ymd("2020-03-14"),
                      ymd("2020-04-04"),
                      by = "days"),
           Beta = matrix(sur.slm_lag11$coefficients[-c(2,3)],ncol = 22)[n,],
           tvalue = matrix(sur.slm_lag11$coefficients[-c(2,3)]/sur.slm_lag11$rest.se[-c(2,3)], ncol = 2
  mutate(sig = ifelse(abs(tvalue) > 1.64, "Significant at 5%", "Not Significant at 5%")) %>%
  ggplot(aes(x = Date, y = Beta, color = sig)) +
  geom_point(size = 2) +
  scale_color_manual(values = c("Significant at 5%" = "red", "Not Significant at 5%" = "blue")) +
  geom_hline(yintercept = 0) +
  geom_vline(xintercept = as_date("2020-03-16"), color = "red") +
  theme_tufte()
```



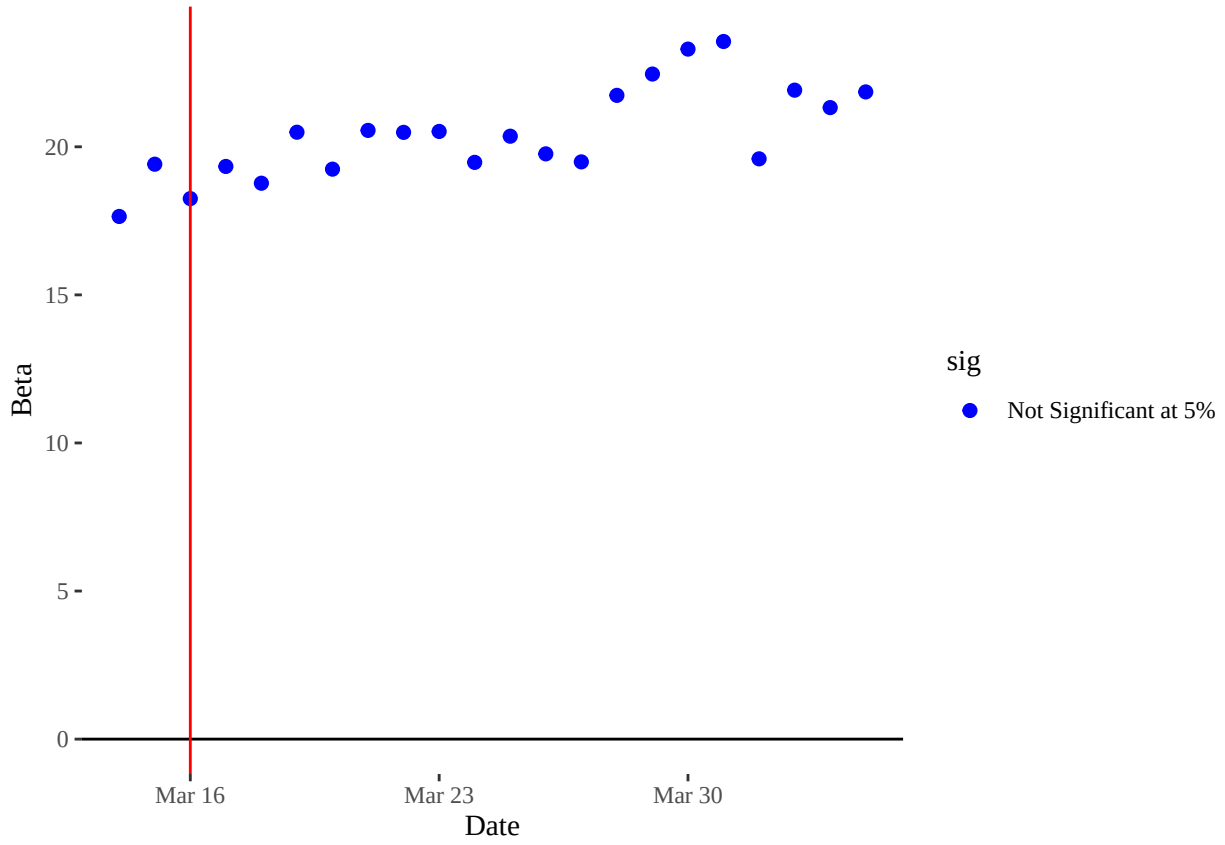
Boxplot of temperatures by date

```
ggplot(data = covid19_spain, aes(x = Date, y = Mean_Temp_lag11w, group = Date)) +
  geom_boxplot()
```



Intercept

```
n = 1
data.frame(Date = seq(ymd("2020-03-14"),
                      ymd("2020-04-04"),
                      by = "days"),
           Beta = matrix(sur.slm_lag11$coefficients[-c(2,3)],ncol = 22)[n,],
           tvalue = matrix(sur.slm_lag11$coefficients[-c(2,3)]/sur.slm_lag11$rest.se[-c(2,3)], ncol = 2
  mutate(sig = ifelse(abs(tvalue) > 1.64, "Significant at 5%", "Not Significant at 5%")) %>%
  ggplot(aes(x = Date, y = Beta, color = sig)) +
  geom_point(size = 2) +
  scale_color_manual(values = c("Significant at 5%" = "red", "Not Significant at 5%" = "blue")) +
  geom_hline(yintercept = 0) +
  geom_vline(xintercept = as_date("2020-03-16"), color = "red") +
  theme_tufte()
```


20
15
10
5
0
Beta
Mar 16
Mar 23
Mar 30
Date
sig
Not Significant at 5%