Setup

```
library(sf)
library(tidyverse)
library(spdep)
library(tmap)
library(spatialreg)

election <- read_sf("export/2004_Election_Counties.shp") %>%
  st_transform(crs = st_crs("EPSG:2163"))

centroids <- st_centroid(election)$geometry

election_neighbors <- election %>%
  poly2nb()

election_weighted <- election_neighbors %>%
  nb2listw(
    style = "W",
    zero.policy = TRUE
  )
```

Question 1:

Use `lm()` to estimate `Bush_pct ~ pcincome` using ordinary least squares (OLS). Plot the **residuals** on a map (look back to R Module 7) and **test the residuals for spatial autocorrelation**. Provide both an example of your map and the results from your spatial autocorrelation test in your R Markdown report.

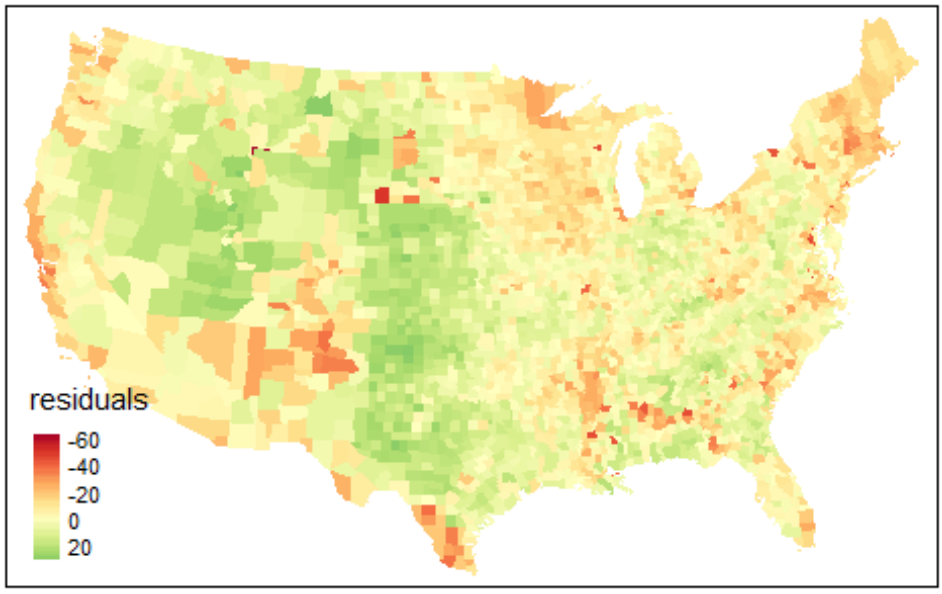
```
lm <- lm(Bush_pct ~ pcincome, data = election)
summary(lm)

##
## Call:
## lm(formula = Bush_pct ~ pcincome, data = election)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -63.434  -7.927   0.479   8.755  31.904
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  6.343e+01  8.893e-01  71.329  < 2e-16 ***
## pcincome    -1.592e-04  4.832e-05  -3.294 0.000997 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 12.74 on 3109 degrees of freedom
## Multiple R-squared:  0.003479,   Adjusted R-squared:  0.003158
## F-statistic: 10.85 on 1 and 3109 DF,  p-value: 0.0009974
```

```r
election$residuals <- lm$residuals

tm_shape(election) +
  tm_polygons(
    col = "residuals",
    border.col = NULL,
    style = "cont"
  )
```

```
## Variable(s) "residuals" contains positive and negative values, so midpoint
is set to 0. Set midpoint = NA to show the full spectrum of the color
palette.
```




```r
moran_residuals <-
  moran.test(
    x = election$residuals,
    listw = election_weighted,
    zero.policy = TRUE,
    alternative = "two.sided"
  )

moran_residuals
```

```
##
##  Moran I test under randomisation
##
## data:  election$residuals
```

```
## weights: election_weighted  n reduced by no-neighbour observations
##
##
## Moran I statistic standard deviate = 51.138, p-value < 2.2e-16
## alternative hypothesis: two.sided
## sample estimates:
## Moran I statistic       Expectation          Variance
##      0.5501302998     -0.0003219575      0.0001158637
```

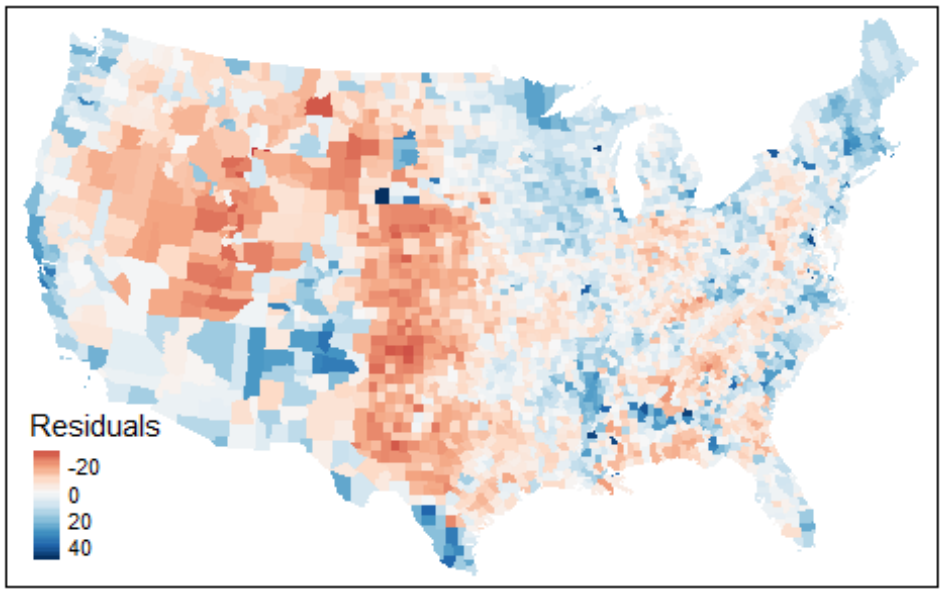
Question 2:

Modeling `Kerry_pct ~ pcincome`, perform the following steps: - Evaluate the relationship between the variables using `lm()` - Plot the resulting residuals, then test for autocorrelation with `moran.test()`. Provide your map!

```
kerry_lm <- lm(Kerry_pct ~ pcincome, data = election)

election$kerry_lm_res <- kerry_lm$residuals

tm_shape(election) +
  tm_polygons(
    col = "kerry_lm_res",
    border.col = NULL,
    palette = "RdBu",
    style = "cont",
    midpoint = 0,
    title = "Residuals"
  )
```




```
kerry_moran <- moran.test(
  election$kerry_lm_res,
  listw = election_weighted,
  zero.policy = TRUE,
  alternative = "two.sided"
)
kerry_moran

##
##  Moran I test under randomisation
##
## data:  election$kerry_lm_res
## weights: election_weighted  n reduced by no-neighbour observations
##
##
## Moran I statistic standard deviate = 51.382, p-value < 2.2e-16
## alternative hypothesis: two.sided
## sample estimates:
## Moran I statistic       Expectation          Variance
##      0.5527928269     -0.0003219575      0.0001158778
```

- Estimate the same relationship, using the spatial lag model (`spatialreg::lagsarlm()`)

```
library(spatialreg)
kerry_lag <- lagsarlm(
  Kerry_pct ~ pcincome,
  data = election,
```

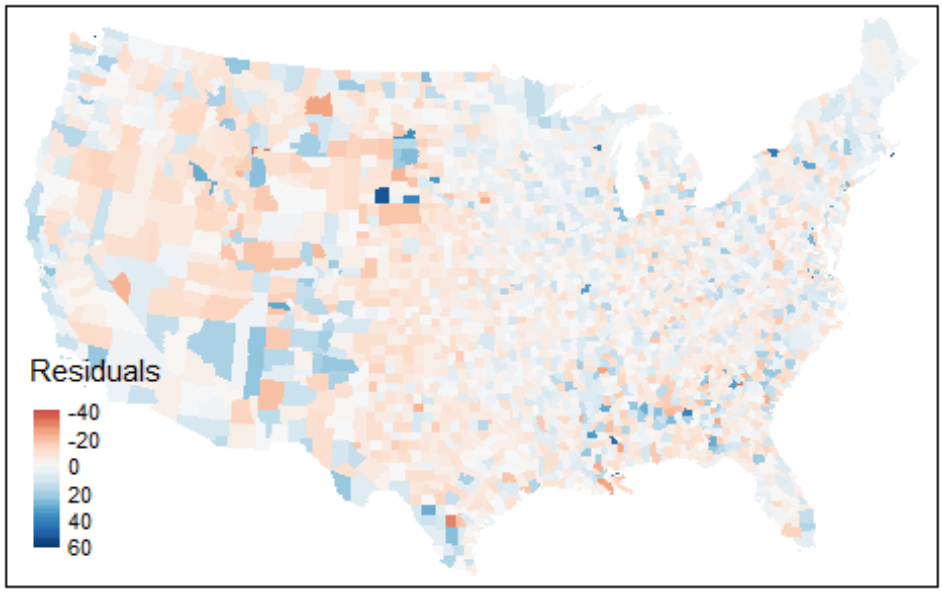
```
  listw = election_weighted,
  zero.policy = TRUE
)

summary(kerry_lag)
```

- Perform a Moran's I test on the residuals from the lag model and report your results. Plot the residuals from the spatial lag model, and include in your report.

```
election$kerry_lag_res <- kerry_lag$residuals

tm_shape(election) +
  tm_polygons(
    col = "kerry_lag_res",
    border.col = NULL,
    palette = "RdBu",
    style = "cont",
    midpoint = 0,
    title = "Residuals"
  )
```




```
kerry_lag_moran <- moran.test(
  election$kerry_lag_res,
  election_weighted, ,
  zero.policy = TRUE,
  alternative = "two.sided"
```

```
)
kerry_lag_moran

##
##  Moran I test under randomisation
##
## data:  election$kerry_lag_res
## weights: election_weighted  n reduced by no-neighbour observations
##
##
## Moran I statistic standard deviate = -3.3346, p-value = 0.0008542
## alternative hypothesis: two.sided
## sample estimates:
## Moran I statistic       Expectation          Variance
##     -0.0361970075     -0.0003219575      0.0001157424
```

- Is there evidence of remaining spatial autocorrelation in the residuals?

No, as the value of I from the moran.test is close to 0, there is little remaining spatial autocorrelation.

Question 3:

Using your `Kerry_pct ~ pcincome` analysis, perform the spatial error model. Provide the results of the model and plot its residuals on a map. Then, perform Moran's I on the resulting residuals, and provide the Moran's I and p-value. Explain any differences in the values between: - The coefficient variables (λ and ρ), - The p-values in the spatial regression models, - The Moran's I statistics, and, - The p-values from the Moran's I

```
kerry_error <- errorsarlm(
  formula = Kerry_pct ~ pcincome,
  data = election,
  listw = election_weighted,
  zero.policy = TRUE
)

summary(kerry_error)

##
## Call:errorsarlm(formula = Kerry_pct ~ pcincome, data = election, listw =
election_weighted,
##     zero.policy = TRUE)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -43.5561  -5.5679  -1.1063   4.4040  52.7563
##
## Type: error
## Regions with no neighbours included:
##  36 691 711 883
```

```
## Coefficients: (asymptotic standard errors)
##                Estimate  Std. Error z value Pr(>|z|)
## (Intercept)  3.9847e+01  9.7530e-01 40.8563   <2e-16
## pcincome    -1.9955e-05  4.1196e-05 -0.4844   0.6281
##
## Lambda: 0.75979, LR test value: 1803.8, p-value: < 2.22e-16
## Asymptotic standard error: 0.014301
##     z-value: 53.129, p-value: < 2.22e-16
## Wald statistic: 2822.7, p-value: < 2.22e-16
##
## Log likelihood: -11389.23 for error model
## ML residual variance (sigma squared): 77.035, (sigma: 8.7769)
## Number of observations: 3111
## Number of parameters estimated: 4
## AIC: 22786, (AIC for lm: 24588)
```

```
election$kerry_err_res <- kerry_error$residuals

kerry_error_moran <- moran.test(
  election$kerry_err_res,
  listw = election_weighted,
  zero.policy = TRUE,
  alternative = "two.sided"
)

library(broom)
options(pillar.sigfig = 5)


# Regression Coefficients
bind_rows(
  tidy(kerry_lag)[1, ],
  tidy(kerry_error)[3, ]
)
```

```
## # A tibble: 2 x 5
##   term   estimate std.error statistic p.value
##   <chr>     <dbl>     <dbl>     <dbl>   <dbl>
## 1 rho     0.73380  0.015051    48.754       0
## 2 lambda  0.75979  0.014301    53.129       0
```

```
# Autocorrelation Coefficients

moran_names <-
  c(
    "Moran's I",
    "Expectation",
    "Variance",
    "Standard Dev.",
    "p-value",
```

```
    "Method",
    "Alternative"
  )


tribble(
  ~Model,
  "Spatial Lag",
  "Spatial Error"
) %>%
  bind_cols(bind_rows(
    tidy(kerry_lag_moran) %>%
      `colnames<-`(moran_names),
    tidy(kerry_error_moran) %>%
      `colnames<-`(moran_names)
  ))
```

```
## # A tibble: 2 x 8
##   Model         `Moran's I` Expectation   Variance `Standard Dev.`     `p-
value` Method                 Alternative
##   <chr>               <dbl>       <dbl>      <dbl>           <dbl>
<dbl> <chr>                  <chr>
## 1 Spatial Lag     -0.036197 -0.00032196 0.00011574         -3.3346
0.00085416    Moran I test under ra~ two.sided
## 2 Spatial Error   -0.056214 -0.00032196 0.00011578         -5.1944
0.00000020541 Moran I test under ra~ two.sided
```