Spatial autocorrelation

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Introduction

This .Rmd file is to test the spatial autocorrelation in our black carp data file, and try to find the best distance that reduces the spatial autocorrelation when doing subsampling. In this file, we:

1. Use moran's I test to test the global spatial autocorrelation in our dataset.
2. Use the correlog plots to examine how spatial autocorrelation changes with distances.
3. Use the variogram to further test point 2.
4. Subsample.

```
library(gstat)
library(ggplot2)
library(dplyr)
library(spdep)
library(sp)
library(nlme)
library(ape)
library(MuMIn)
library(raster)
library(ncf)
library(knitr)
```

```
## Import location data
location <- read.csv("location_no_temps.csv")
location <- unique(location) # remove duplicating locations

# Clean the data
carp <- read.csv("eddie_carp_new.csv")
carp.r <- carp %>%
  filter(sex != "male") %>% # keep the non-male data points
  distinct(location, .keep_all = TRUE) # remove all repeating locations

## Download one file to get the spatial points
# (this defines what projection to use when converting to spatial objects)
tmin.1979 <- brick("cpc/tmin.1979.nc", varname = "tmin")
```

```
## Loading required namespace: ncdf4
```

```
tmin.1979<-rotate(tmin.1979)
```

Calculate the residuals from the linear model

```r
# Define the model
lm.annual <- lm(log(carp.r$AAM)~carp.r$AnnualTemp) # Annual temperature
lm.cold <- lm(log(carp.r$AAM)~carp.r$ColdTemp) # Cold temperature
lm.warm <- lm(log(carp.r$AAM)~carp.r$WarmTemp) # Warm temperature

# See the results
summary(lm.annual)
```

```
##
## Call:
## lm(formula = log(carp.r$AAM) ~ carp.r$AnnualTemp)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.45033 -0.15088 -0.02442  0.11877  0.54619
##
## Coefficients:
##                    Estimate Std. Error t value Pr(>|t|)
## (Intercept)        2.027038   0.088922  22.796   2.7e-16 ***
## carp.r$AnnualTemp -0.018853   0.006468  -2.915  0.00828 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2131 on 21 degrees of freedom
## Multiple R-squared:  0.288,  Adjusted R-squared:  0.2541
## F-statistic: 8.495 on 1 and 21 DF,  p-value: 0.008285
```

```r
summary(lm.cold)
```

```
##
## Call:
## lm(formula = log(carp.r$AAM) ~ carp.r$ColdTemp)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.41846 -0.12055 -0.02502  0.09514  0.57767
##
## Coefficients:
##                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)      1.79047    0.04397  40.723  < 2e-16 ***
## carp.r$ColdTemp -0.01190    0.00389  -3.059  0.00596 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.21 on 21 degrees of freedom
## Multiple R-squared:  0.3083, Adjusted R-squared:  0.2753
## F-statistic: 9.359 on 1 and 21 DF,  p-value: 0.005955
```

```r
summary(lm.warm)
```

```
##
## Call:
## lm(formula = log(carp.r$AAM) ~ carp.r$WarmTemp)
##
```

```
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.48388 -0.15016  0.03813  0.11838  0.54909
##
## Coefficients:
##                 Estimate Std. Error t value Pr(>|t|)
## (Intercept)      2.26257    0.30290    7.47 2.43e-07 ***
## carp.r$WarmTemp -0.01943    0.01262   -1.54    0.139
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2394 on 21 degrees of freedom
## Multiple R-squared:  0.1015, Adjusted R-squared:  0.05867
## F-statistic: 2.371 on 1 and 21 DF,  p-value: 0.1385
```

Global spatial autocorrelation

```r
## Make spatial dataframe
coords <- data.frame("long"=location[,3],"lat"=location[,2])
df <- data.frame(a = 1:nrow(location[3]))
spatial.data <- SpatialPointsDataFrame(coords,df,proj4string = tmin.1979@crs)

# Get a distance matrix from all points
dists <- spDists(spatial.data, longlat = TRUE)

## Run the Moran.I test on the residuals
Moran.annual <- Moran.I(lm.annual$residuals, dists)
Moran.cold <- Moran.I(lm.cold$residuals, dists)

global.moran <- data.frame(
  Model = c("Moran.annual", "Moran.cold"),
  Observed = c(Moran.annual$observed, Moran.cold$observed),
  Expected = c(Moran.annual$expected, Moran.cold$expected),
  sd = c(Moran.annual$sd, Moran.cold$sd),
  p.value = c(Moran.annual$p.value, Moran.cold$p.value)
)

kable(global.moran)
```

Model	Observed	Expected	sd	p.value
Moran.annual	-0.0276980	-0.0454545	0.0316840	0.5751899
Moran.cold	-0.0330776	-0.0454545	0.0317925	0.6970518

There is no global spatial autocorrelation for the entire dataset.

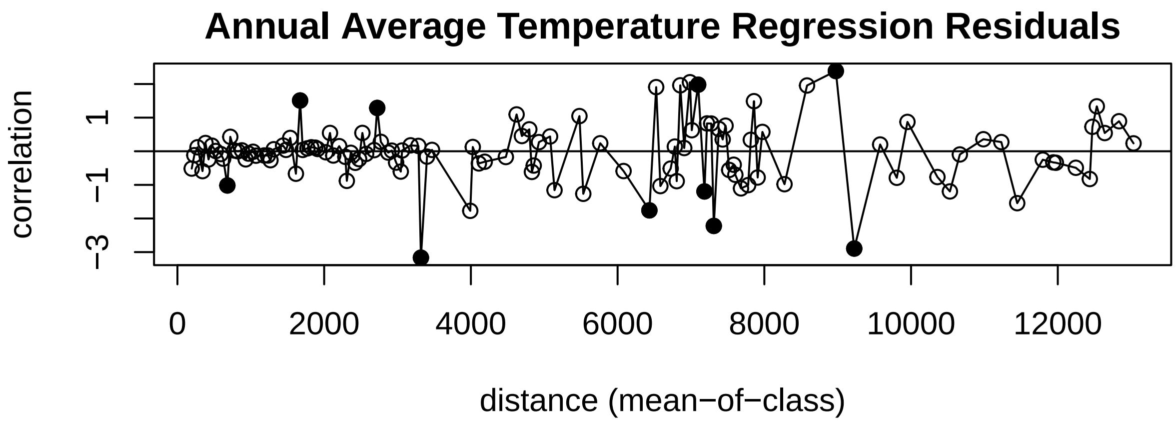
Correlog plots - local spatial autocorrelation

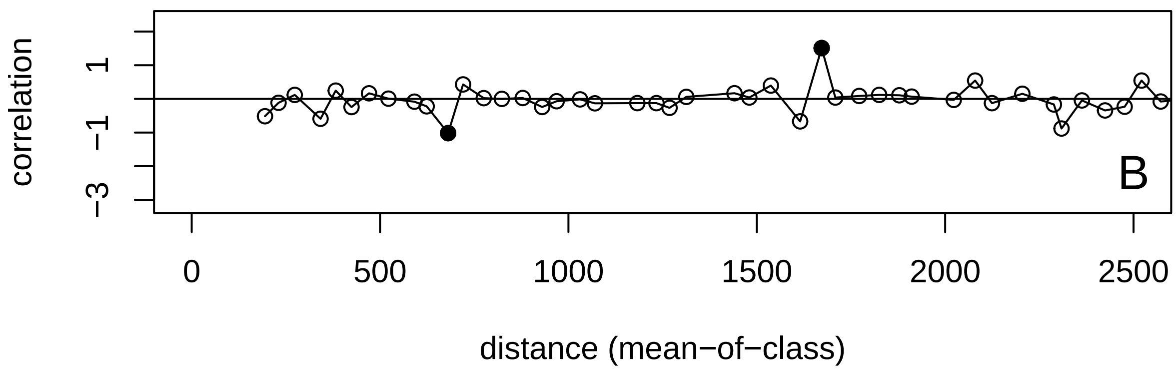
```r
## Annual temperature
par(mfrow=c(2,1),mar=c(4,4,2,2))

# Use the coorelog function to develop the relationship
```

```r
test <- correlog(coords$long, coords$lat, lm.annual$residuals,
                 increment=50, resamp=500, latlon=T)
```

```
## 50  of  500 100  of  500 150  of  500 200  of  500 250  of  500 300  of  500 350  of  500 400  of  5
```

```r
# Plot with the entire distance range
plot(test, main="Annual Average Temperature Regression Residuals")
abline(h=0)
text(17400, min(test$correlation)+1, "A", cex=1.5)

# Reduce the distance range to 2500 km
plot(test, main="", xlim=c(0,2500))
abline(h=0)
text(2500, min(test$correlation)+1, "B", cex=1.5)
```



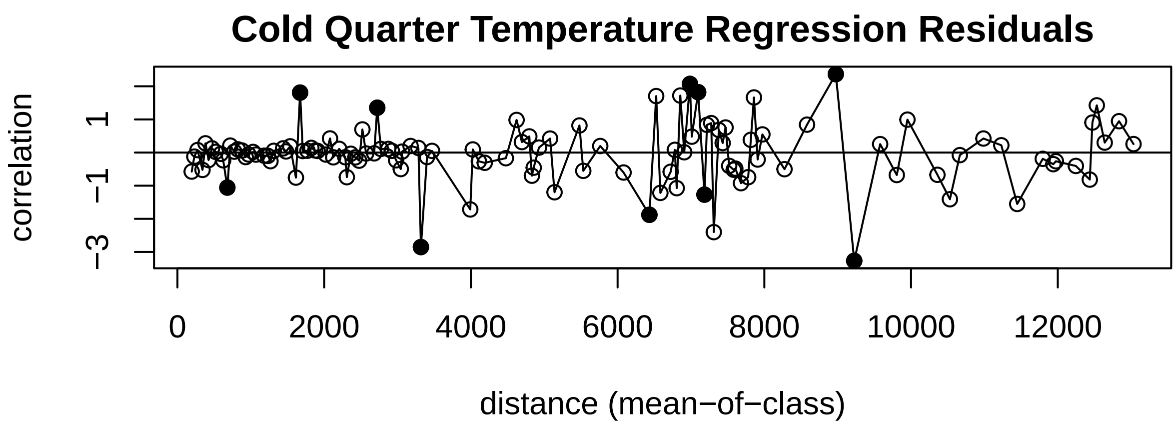


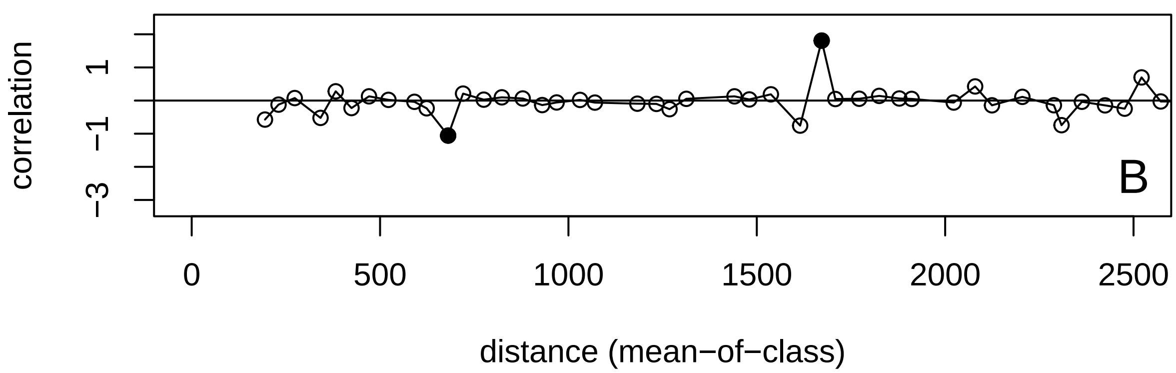

```r
## Cold temperature
par(mfrow=c(2,1),mar=c(4,4,2,2))

# Use the coorelog function to develop the relationship
test <- correlog(coords$long, coords$lat, lm.cold$residuals,
                 increment=50, resamp=500, latlon=T)
```

```
## 50  of  500 100  of  500 150  of  500 200  of  500 250  of  500 300  of  500 350  of  500 400  of  5
```

```r
# Plot with the entire distance range
plot(test, main="Cold Quarter Temperature Regression Residuals")
abline(h=0)
text(17400, min(test$correlation)+1, "A", cex=1.5)
```

```r
# Reduce the distance range to 2500 km
plot(test, main="", xlim=c(0,2500))
abline(h=0)
text(2500, min(test$correlation)+1, "B", cex=1.5)
```

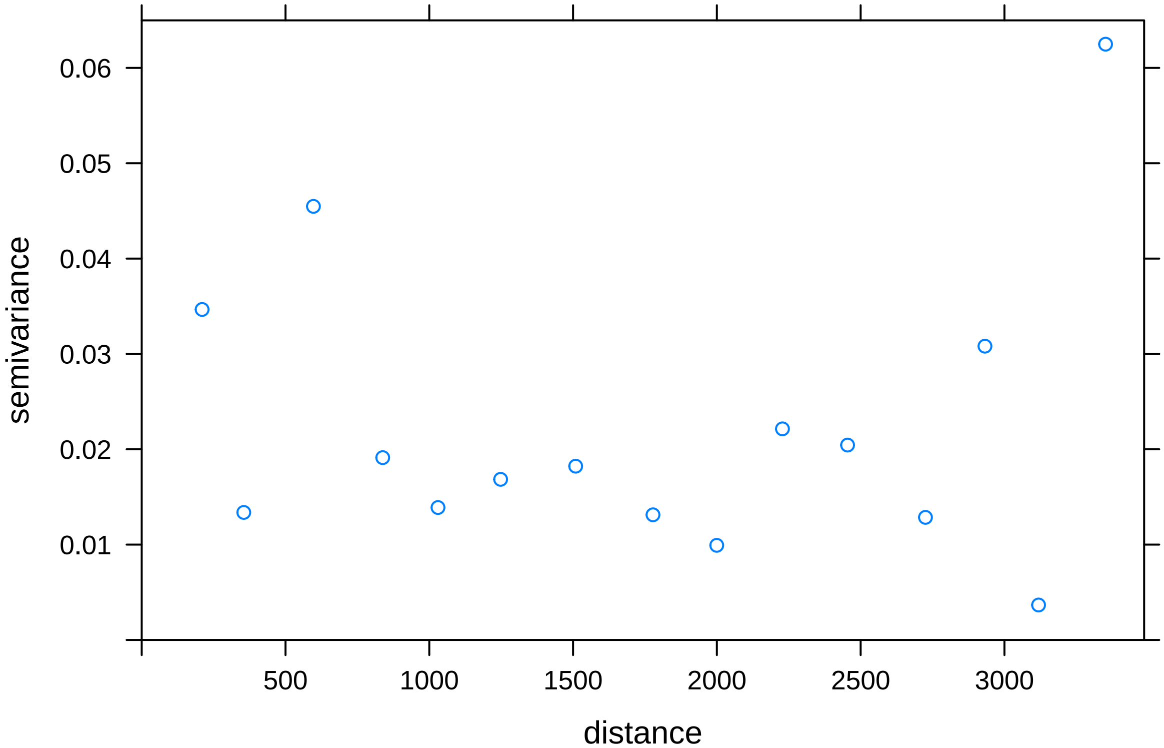




In general, the correlog plots suggest that for both temperature, 600 km is a good distance to reduce local spatial autocorrelation.

Variogram

```r
## Create a data frame to store the necessary information
vario.data <- data.frame(residuals = lm.annual$residuals,
                         x = coords$long, y = coords$lat)

# Turn them to spatial points using our projection
geo.spatial<-SpatialPoints(coords, proj4string = tmin.1979@crs)


## Variogram
vario <- variogram(vario.data$residuals~1, data = geo.spatial)
plot(vario)
```



If we pick 250 km as the cutoff distance for sub-sampling, we would have 20 location points.

If we pick 500 km as the cutoff distance for sub-sampling, we would have only 13 location points.

Subsampling examination