Assignment 6: GLMs (Linear Regressios, ANOVA, & t-tests)

Nicole Eastman

OVERVIEW

This exercise accompanies the lessons in Environmental Data Analytics on generalized linear models.

Directions

1. Rename this file `<FirstLast>_A06_GLMs.Rmd` (replacing `<FirstLast>` with your first and last name).
2. Change "Student Name" on line 3 (above) with your name.
3. Work through the steps, **creating code and output** that fulfill each instruction.
4. Be sure to **answer the questions** in this assignment document.
5. When you have completed the assignment, **Knit** the text and code into a single PDF file.

Set up your session

1. Set up your session. Check your working directory. Load the tidyverse, agricolae and other needed packages. Import the *raw* NTL-LTER raw data file for chemistry/physics (`NTL-LTER_Lake_ChemistryPhysics_Raw.csv`). Set date columns to date objects.

2. Build a ggplot theme and set it as your default theme.

```
# 1 Set-up
getwd()
```

```
## [1] "/home/guest/R/EDA Fall 2022"
```

```
library(tidyverse)
```

```
## -- Attaching packages --------------------------------------- tidyverse 1.3.2 --
## v ggplot2 3.3.6      v purrr   0.3.4
## v tibble  3.1.8      v dplyr   1.0.10
## v tidyr   1.2.0      v stringr 1.4.1
## v readr   2.1.2      v forcats 0.5.2
## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
```

```
library(agricolae)
library(dplyr)
library(corrplot)
```

```
## corrplot 0.92 loaded
```

```
Chem.Physics <- read.csv("Data/Raw/NTL-LTER_Lake_ChemistryPhysics_Raw.csv", stringsAsFactors = TRUE)
Chem.Physics$sampledate <- as.Date(Chem.Physics$sampledate, format = "%m/%d/%y")

# 2 Theme
mytheme <- theme_classic(base_size = 14) + theme(axis.text = element_text(color = "black"),
```

```
    legend.position = "top")
theme_set(mytheme)
```

Simple regression

Our first research question is: Does mean lake temperature recorded during July change with depth across all lakes?

3. State the null and alternative hypotheses for this question: > Answer: H0: Mean lake temperature during July does not correlate with depth across all lakes Ha: There is a significant correlation between lake tempuratue and depth across all lakes
4. Wrangle your NTL-LTER dataset with a pipe function so that the records meet the following criteria:

- Only dates in July.
- Only the columns: `lakename`, `year4`, `daynum`, `depth`, `temperature_C`
- Only complete cases (i.e., remove NAs)

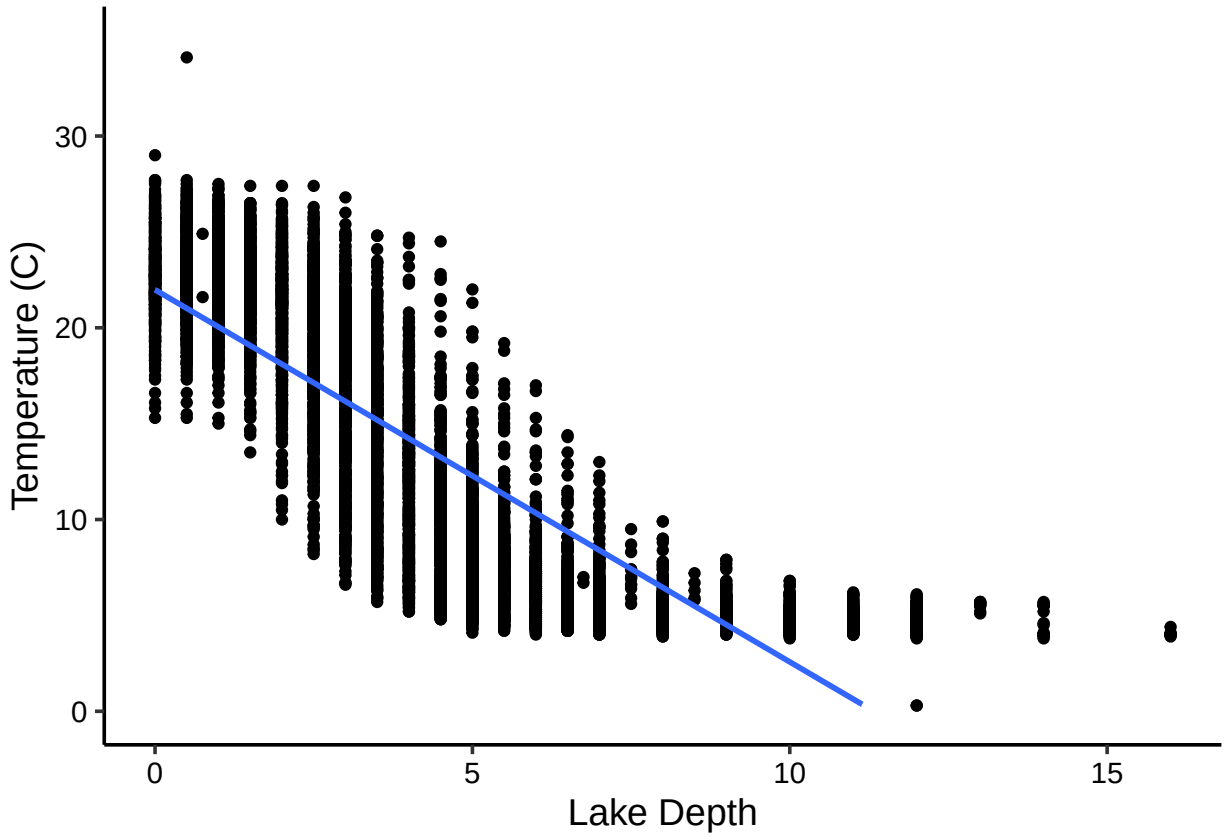
5. Visualize the relationship among the two continuous variables with a scatter plot of temperature by depth. Add a smoothed line showing the linear model, and limit temperature values from 0 to 35 °C. Make this plot look pretty and easy to read.

```
# 4 Wrangling Data
Chem.Subset <- Chem.Physics %>%
    filter(daynum %in% c(183:213)) %>%
    select(lakename:daynum, depth, temperature_C) %>%
    na.omit()


# 5 Scatter Plot
TempbyDepth <- ggplot(Chem.Subset, aes(x = depth, y = temperature_C)) + ylim(0, 35) +
    geom_point() + geom_smooth(method = "lm") + labs(x = "Lake Depth", y = "Temperature (C)")
print(TempbyDepth)
```

```
## `geom_smooth()` using formula 'y ~ x'
```

```
## Warning: Removed 24 rows containing missing values (geom_smooth).
```



6. Interpret the figure. What does it suggest with regards to the response of temperature to depth? Do the distribution of points suggest anything about the linearity of this trend?

   Answer: The graph suggests that temperature in celsius generally decreases as the lake depth increases. There is a substantial distribution of points along the line of best fit which suggests that the linearity (or association) of this trend is not very strong.

7. Perform a linear regression to test the relationship and display the results

```
# 7 Linear Regression
Chem.Regression <- lm(Chem.Subset$temperature_C ~ Chem.Subset$depth)
summary(Chem.Regression)
```

```
##
## Call:
## lm(formula = Chem.Subset$temperature_C ~ Chem.Subset$depth)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -9.5606 -3.0380  0.0872  2.9872 13.4706
##
## Coefficients:
##                    Estimate Std. Error t value Pr(>|t|)
## (Intercept)        21.98318    0.06840   321.4   <2e-16 ***
## Chem.Subset$depth -1.94086    0.01179  -164.7   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
## Residual standard error: 3.852 on 9671 degrees of freedom
## Multiple R-squared:  0.7371, Adjusted R-squared:  0.7371
## F-statistic: 2.712e+04 on 1 and 9671 DF,  p-value: < 2.2e-16
```

8. Interpret your model results in words. Include how much of the variability in temperature is explained by changes in depth, the degrees of freedom on which this finding is based, and the statistical significance of the result. Also mention how much temperature is predicted to change for every 1m change in depth.

   Answer: 73.71% of the variability in temperature is explained by changes in depth and the p-value is less than 0.001 which indicates the correlation between the two variables is statistically significant. The degrees of freedom for this model is 9671 due to the large volume of recorded observations.

Multiple regression

Let's tackle a similar question from a different approach. Here, we want to explore what might the best set of predictors for lake temperature in July across the monitoring period at the North Temperate Lakes LTER.

9. Run an AIC to determine what set of explanatory variables (year4, daynum, depth) is best suited to predict temperature.

10. Run a multiple regression on the recommended set of variables.

```
# 9 AIC
TempAIC <- lm(data = Chem.Subset, temperature_C ~ year4 + daynum + depth)
step(TempAIC)
```

```
## Start:  AIC=25998.22
## temperature_C ~ year4 + daynum + depth
##
##          Df Sum of Sq    RSS   AIC
## <none>                142056 25998
## - year4   1       201 142257 26010
## - daynum  1      1237 143293 26080
## - depth   1    402549 544605 38995
```

```
##
## Call:
## lm(formula = temperature_C ~ year4 + daynum + depth, data = Chem.Subset)
##
## Coefficients:
## (Intercept)        year4       daynum        depth
##   -18.19700      0.01611      0.04024     -1.94133
```

```
# 10 Multiple Regression
Temp.Best.Regression <- lm(data = Chem.Subset, temperature_C ~ year4 + daynum + depth)
summary(Temp.Best.Regression)
```

```
##
## Call:
## lm(formula = temperature_C ~ year4 + daynum + depth, data = Chem.Subset)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -9.6857 -3.0267  0.1055  2.9937 13.6038
##
## Coefficients:
```

```
##               Estimate Std. Error  t value Pr(>|t|)
## (Intercept) -18.196998   8.741236   -2.082 0.037392 *
## year4         0.016113   0.004353    3.701 0.000216 ***
## daynum        0.040237   0.004385    9.176  < 2e-16 ***
## depth        -1.941328   0.011728 -165.528  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.833 on 9669 degrees of freedom
## Multiple R-squared:  0.7398, Adjusted R-squared:  0.7397
## F-statistic:  9162 on 3 and 9669 DF,  p-value: < 2.2e-16
```

11. What is the final set of explanatory variables that the AIC method suggests we use to predict temperature in our multiple regression? How much of the observed variance does this model explain? Is this an improvement over the model using only depth as the explanatory variable?

    Answer: The AIC method suggests we use all three variables: year4, daynum, and depth to predict temperature in the regression. The model explains 73.97% of the observed variance which is a slight improvement from the linear regression only using depth as an explanatory variable.

Analysis of Variance

12. Now we want to see whether the different lakes have, on average, different temperatures in the month of July. Run an ANOVA test to complete this analysis. (No need to test assumptions of normality or similar variances.) Create two sets of models: one expressed as an ANOVA models and another expressed as a linear model (as done in our lessons).

```
# 12 Anova and Lm tests
Chem.aov <- aov(data = Chem.Subset, temperature_C ~ lakename)
summary(Chem.aov)
```

```
##               Df Sum Sq Mean Sq F value Pr(>F)
## lakename       8  22188  2773.5   51.18 <2e-16 ***
## Residuals   9664 523706    54.2
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
Chem.lm <- lm(data = Chem.Subset, temperature_C ~ lakename)
summary(Chem.lm)
```

```
##
## Call:
## lm(formula = temperature_C ~ lakename, data = Chem.Subset)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -10.773  -6.612  -2.673   7.657  23.813
##
## Coefficients:
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)                 17.6664     0.6507  27.151  < 2e-16 ***
## lakenameCrampton Lake       -2.1851     0.7565  -2.889 0.003879 **
## lakenameEast Long Lake      -7.3795     0.6915 -10.671  < 2e-16 ***
## lakenameHummingbird Lake    -6.6828     0.9571  -6.982 3.09e-12 ***
## lakenamePaul Lake           -3.8234     0.6666  -5.735 1.00e-08 ***
```

```
## lakenamePeter Lake        -4.3162     0.6652  -6.489 9.08e-11 ***
## lakenameTuesday Lake      -6.5937     0.6777  -9.730  < 2e-16 ***
## lakenameWard Lake         -3.2078     0.9437  -3.399 0.000679 ***
## lakenameWest Long Lake    -6.0542     0.6893  -8.783  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 7.361 on 9664 degrees of freedom
## Multiple R-squared:  0.04064,    Adjusted R-squared:  0.03985
## F-statistic: 51.18 on 8 and 9664 DF,  p-value: < 2.2e-16
```

13. Is there a significant difference in mean temperature among the lakes? Report your findings.

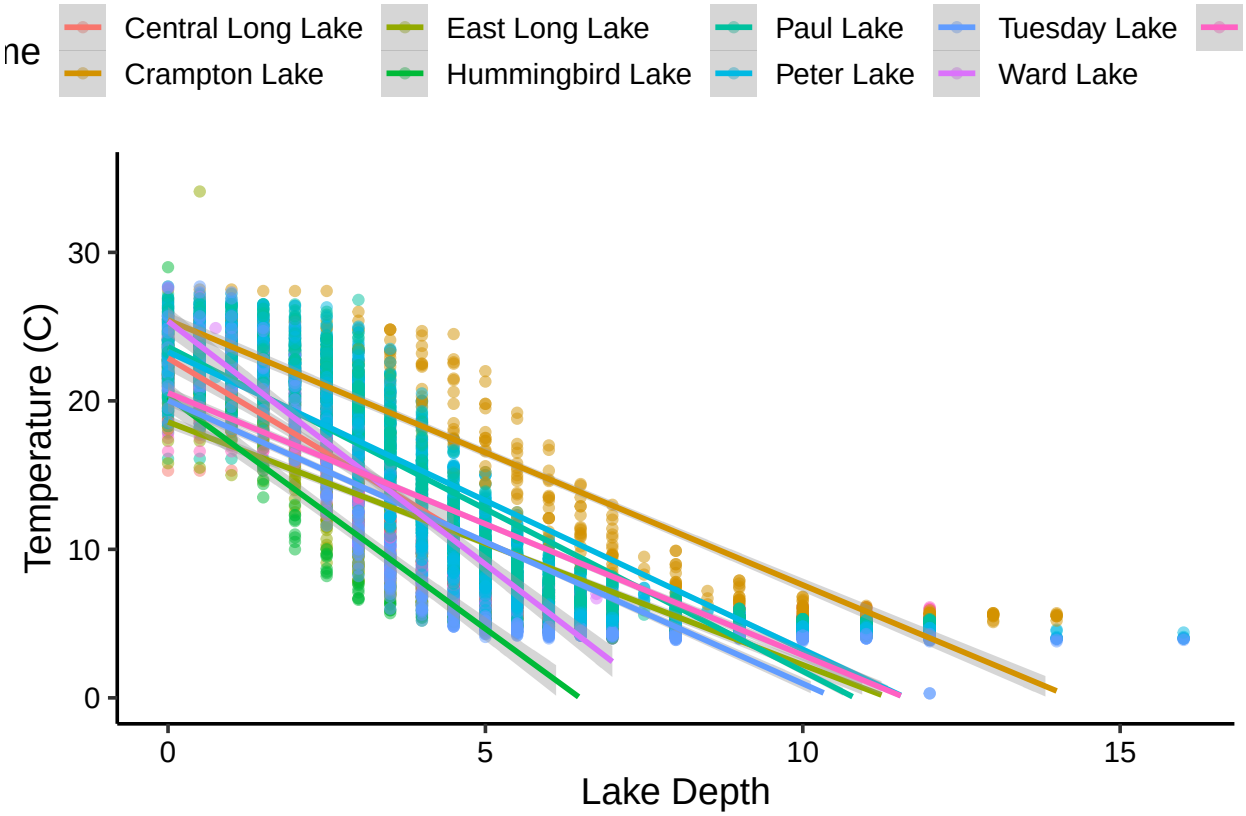
    Answer: Yes, there is a significant difference in mean temperature among the lakes because the p-value is less than 0.05 which indicates the correlation between temperature and lake is significant.

14. Create a graph that depicts temperature by depth, with a separate color for each lake. Add a geom_smooth (method = "lm", se = FALSE) for each lake. Make your points 50 % transparent. Adjust your y axis limits to go from 0 to 35 degrees. Clean up your graph to make it pretty.

```
# 14. Plotting Temp by Depth
Temp.Lake.Plot <- ggplot(Chem.Subset, aes(x = depth, y = temperature_C, col = lakename)) +
    ylim(0, 35) + geom_point(alpha = 0.5) + geom_smooth(method = "lm") + labs(x = "Lake Depth",
    y = "Temperature (C)")
print(Temp.Lake.Plot)
```

```
## `geom_smooth()` using formula 'y ~ x'
```

```
## Warning: Removed 72 rows containing missing values (geom_smooth).
```



15. Use the Tukey's HSD test to determine which lakes have different means.

```
# 15 Tukey HSD Test
Chem.HSD <- TukeyHSD(Chem.aov)
Chem.HSD
```

```
##   Tukey multiple comparisons of means
##     95% family-wise confidence level
##
## Fit: aov(formula = temperature_C ~ lakename, data = Chem.Subset)
##
## $lakename
##                                          diff        lwr        upr     p adj
## Crampton Lake-Central Long Lake    -2.18508757 -4.5319912  0.1618160 0.0915179
## East Long Lake-Central Long Lake   -7.37946293 -9.5249061 -5.2340198 0.0000000
## Hummingbird Lake-Central Long Lake -6.68276989 -9.6520798 -3.7134600 0.0000000
## Paul Lake-Central Long Lake        -3.82336936 -5.8915944 -1.7551443 0.0000004
## Peter Lake-Central Long Lake       -4.31624752 -6.3799766 -2.2525184 0.0000000
## Tuesday Lake-Central Long Lake     -6.59373914 -8.6961647 -4.4913136 0.0000000
## Ward Lake-Central Long Lake        -3.20778556 -6.1355040 -0.2800671 0.0195251
## West Long Lake-Central Long Lake   -6.05416916 -8.1927792 -3.9155591 0.0000000
## East Long Lake-Crampton Lake       -5.19437536 -6.5946962 -3.7940545 0.0000000
## Hummingbird Lake-Crampton Lake     -4.49768232 -6.9825914 -2.0127732 0.0000007
## Paul Lake-Crampton Lake            -1.63828179 -2.9171590 -0.3594045 0.0023129
## Peter Lake-Crampton Lake           -2.13115995 -3.4027534 -0.8595665 0.0000072
## Tuesday Lake-Crampton Lake         -4.40865157 -5.7421303 -3.0751729 0.0000000
## Ward Lake-Crampton Lake            -1.02269799 -3.4577560  1.4123600 0.9307880
```

```
## West Long Lake-Crampton Lake       -3.86908159 -5.2589107 -2.4792525 0.0000000
## Hummingbird Lake-East Long Lake     0.69669304 -1.5988991  2.9922852 0.9905616
## Paul Lake-East Long Lake            3.55609357  2.7014024  4.4107847 0.0000000
## Peter Lake-East Long Lake           3.06321541  2.2194620  3.9069688 0.0000000
## Tuesday Lake-East Long Lake         0.78572379 -0.1486934  1.7201409 0.1828556
## Ward Lake-East Long Lake            4.17167737  1.9301428  6.4132120 0.0000003
## West Long Lake-East Long Lake       1.32529377  0.3120836  2.3385039 0.0016418
## Paul Lake-Hummingbird Lake          2.85940053  0.6358062  5.0829949 0.0021745
## Peter Lake-Hummingbird Lake         2.36652237  0.1471092  4.5859355 0.0263810
## Tuesday Lake-Hummingbird Lake       0.08903074 -2.1664094  2.3444709 1.0000000
## Ward Lake-Hummingbird Lake          3.47498433  0.4355186  6.5144501 0.0117238
## West Long Lake-Hummingbird Lake     0.62860073 -1.6606065  2.9178079 0.9952002
## Peter Lake-Paul Lake               -0.49287816 -1.1146082  0.1288519 0.2521516
## Tuesday Lake-Paul Lake             -2.77036979 -3.5104805 -2.0302590 0.0000000
## Ward Lake-Paul Lake                 0.61558380 -1.5521583  2.7833259 0.9939613
## West Long Lake-Paul Lake           -2.23079980 -3.0681906 -1.3934090 0.0000000
## Tuesday Lake-Peter Lake            -2.27749162 -3.0049438 -1.5500394 0.0000000
## Ward Lake-Peter Lake                1.10846196 -1.0549910  3.2719149 0.8108720
## West Long Lake-Peter Lake          -1.73792164 -2.5641457 -0.9116976 0.0000000
## Ward Lake-Tuesday Lake              3.38595358  1.1855572  5.5863500 0.0000641
## West Long Lake-Tuesday Lake         0.53956999 -0.3790495  1.4581895 0.6673292
## West Long Lake-Ward Lake           -2.84638360 -5.0813788 -0.6113884 0.0025399
```

16.From the findings above, which lakes have the same mean temperature, statistically speaking, as Peter Lake? Does any lake have a mean temperature that is statistically distinct from all the other lakes?

Answer: Ward Lake' and Paul Lake's mean temperature is statistically the same as Peter Lake's mean temperature. Central Lake is statistically distinct from the others.

17. If we were just looking at Peter Lake and Paul Lake. What's another test we might explore to see whether they have distinct mean temperatures?

    Answer: The HSD test and the two-sample T-test will identify whether Peter Lake and Paul Lake have distinct mean temperatures as well.

18. Wrangle the July data to include only records for Crampton Lake and Ward Lake. Run the two-sample T-test on these data to determine whether their July temperature are same or different. What does the test say? Are the mean temperatures for the lakes equal? Does that match you answer for part 16?

```
# 18 Crampton and Ward Lake Significance
Chem.Crampton.Ward <- Chem.Subset %>%
    filter(lakename %in% c("Crampton Lake", "Ward Lake"))

Chem.TTest <- t.test(Chem.Crampton.Ward$temperature_C ~ Chem.Crampton.Ward$lakename)
Chem.TTest
```

```
##
##  Welch Two Sample t-test
##
## data:  Chem.Crampton.Ward$temperature_C by Chem.Crampton.Ward$lakename
## t = 1.2972, df = 192.4, p-value = 0.1961
## alternative hypothesis: true difference in means between group Crampton Lake and group Ward Lake is n
## 95 percent confidence interval:
##  -0.5323014  2.5776973
## sample estimates:
## mean in group Crampton Lake     mean in group Ward Lake
##                    15.48132                    14.45862
```

```
Chem.Two.Sample <- lm(Chem.Crampton.Ward$temperature_C ~ Chem.Crampton.Ward$lakename)
Chem.Two.Sample
```

```
##
## Call:
## lm(formula = Chem.Crampton.Ward$temperature_C ~ Chem.Crampton.Ward$lakename)
##
## Coefficients:
##                           (Intercept)  Chem.Crampton.Ward$lakenameWard Lake
##                                15.481                                -1.023
```

Answer: The test gives a mean of 15.48 for Crampton Lake and 14.46 for Ward Lake; therefore, the means are similar but not equal. The Tukey test indicated similar means between the two lakes but not quite equal as well.