Assignment 7: GLMs (Linear Regressios, ANOVA, & t-tests)

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OVERVIEW

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

Directions

1. Change "Student Name" on line 3 (above) with your name.
2. Work through the steps, **creating code and output** that fulfill each instruction.
3. Be sure to **answer the questions** in this assignment document.
4. When you have completed the assignment, **Knit** the text and code into a single PDF file.
5. After Knitting, submit the completed exercise (PDF file) to the dropbox in Sakai. Add your last name into the file name (e.g., "Fay_A06_GLMs.Rmd") prior to submission.

The completed exercise is due on Tuesday, March 2 at 1:00 pm.

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
getwd()
```

```
## [1] "Z:/ENV_872_Data_Analy/Environmental_Data_Analytics_2021/Assignments"
```

```
library(tidyverse)
```

```
## Warning: package 'tidyverse' was built under R version 4.0.3
```

```
## -- Attaching packages --------------------------------------- tidyverse 1.3.0 --
```

```
## v ggplot2 3.3.3     v purrr   0.3.4
## v tibble  3.0.6     v dplyr   1.0.3
## v tidyr   1.1.2     v stringr 1.4.0
## v readr   1.4.0     v forcats 0.5.1
```

```
## Warning: package 'ggplot2' was built under R version 4.0.3
```

```
## Warning: package 'tibble' was built under R version 4.0.3
```

```
## Warning: package 'tidyr' was built under R version 4.0.3
```

```
## Warning: package 'readr' was built under R version 4.0.3
```

```
## Warning: package 'purrr' was built under R version 4.0.3
```

```
## Warning: package 'dplyr' was built under R version 4.0.3
```

```
## Warning: package 'stringr' was built under R version 4.0.3
```

```
## Warning: package 'forcats' was built under R version 4.0.3
```

```
## -- Conflicts --------------------------------------- tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
```

```
library(htmltools)
```

```
## Warning: package 'htmltools' was built under R version 4.0.3
```

```
library(agricolae)
```

```
## Warning: package 'agricolae' was built under R version 4.0.3
```

```
library(lubridate)
```

```
## Warning: package 'lubridate' was built under R version 4.0.3
```

```
##
## Attaching package: 'lubridate'
```

```
## The following objects are masked from 'package:base':
##
##     date, intersect, setdiff, union
```

```
NTL_LTER<-read.csv("/ENV_872_Data_Analy/Environmental_Data_Analytics_2021/Data/Raw/NTL-LTER_Lake_Chemis
NTL_LTER$sampledate<-as.Date(NTL_LTER$sampledate, format = "%m/%d/%y")
#2
mytheme<-theme_classic(base_size = 14)+
  theme(axis.text = element_text(color = "black"),
        plot.title = element_text(hjust = 0.5),
        legend.position = "right",
        legend.justification ="center",
        legend.background = element_rect(size=0.5, linetype="solid",
                                         colour ="darkblue"))
```

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: THe null hypothosis is that the mean lake temperature recorded during July does not change with depth across all lakes. Ha: The alternative hypothosis is that the mean lake temperature recorded during July do change with 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.

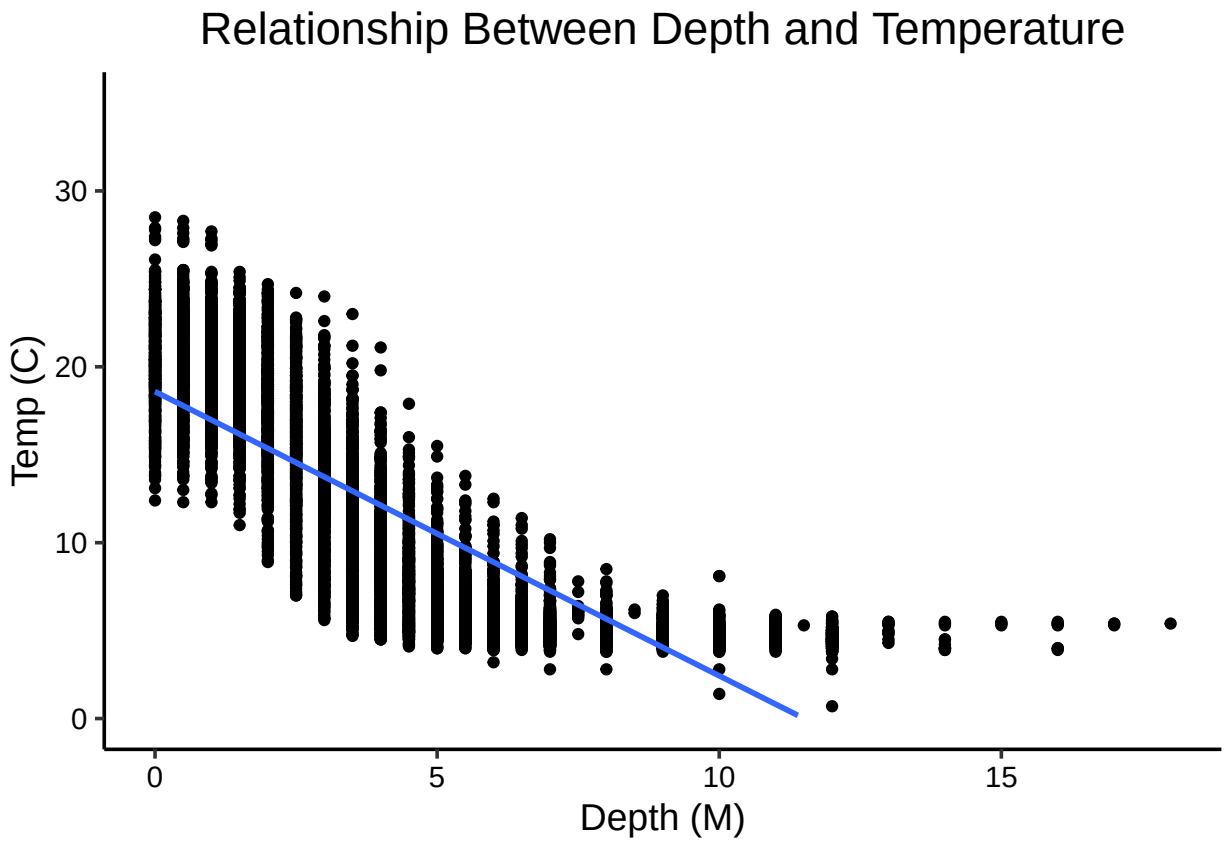
```
#4
NTL_LTER2<-mutate(NTL_LTER, month = month(sampledate))
NTL_LTER3<-
```

```
  NTL_LTER2%>%
  filter(month == "6")%>%
  select(lakename, year4, daynum, depth, temperature_C)%>%
  na.omit()

#5
ggplot(NTL_LTER3, aes(x = depth, y = temperature_C))+
  geom_point()+
  labs(title = "Relationship Between Depth and Temperature")+
  xlab("Depth (M)")+
  ylab("Temp (C)")+
  ylim(0,35)+
  geom_smooth(method="lm")+
  mytheme
```

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

```
## Warning: Removed 29 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 about anything about the linearity of this trend?

   Answer: Temperature decreases with depth up to approximately five meters and then the temperature plataus. There are more points from zero to five meters which decreases the linearity of this graph becuase of the unequal distribution of points.

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

```
#7
lmtempdepth<-lm(data = NTL_LTER3, temperature_C ~ depth)
summary(lmtempdepth)
```

```
##
## Call:
## lm(formula = temperature_C ~ depth, data = NTL_LTER3)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -8.2359 -2.8873 -0.2792  2.6694 15.8990
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 18.59256    0.06427   289.3   <2e-16 ***
## depth       -1.61620    0.01100  -146.9   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.582 on 9501 degrees of freedom
## Multiple R-squared:  0.6943, Adjusted R-squared:  0.6942
## F-statistic: 2.158e+04 on 1 and 9501 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: The model results showed that the realtionship between temperature and depth is significant. We would thus reject our null hypothesis and accept our alternative hypothesis which is that the mean lake temperature recorded during July do change with depth across all lakes. The degrees of freedom in the model is 9501 and there is a R-squared value of 0.6943. THis R squared value is the percent of variance attributed by depth. For every 1m change in depth there is a -1.6 C change in temperature.

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
lmtemp_with_var<-lm(data=NTL_LTER3, temperature_C~depth+year4+daynum)
step(lmtemp_with_var)
```

```
## Start:  AIC=23932.45
## temperature_C ~ depth + year4 + daynum
##
##          Df Sum of Sq    RSS   AIC
## <none>                 117822 23932
## - year4   1        31 117853 23933
## - daynum  1      4040 121862 24251
```

```
## - depth   1    276513 394335 35410
```

```
##
## Call:
## lm(formula = temperature_C ~ depth + year4 + daynum, data = NTL_LTER3)
##
## Coefficients:
## (Intercept)        depth        year4       daynum
##   18.805558    -1.615432    -0.006318     0.074440
```

```
#10
summary(lmtemp_with_var)
```

```
##
## Call:
## lm(formula = temperature_C ~ depth + year4 + daynum, data = NTL_LTER3)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -8.6228 -2.8170 -0.1937  2.7410 15.7528
##
## Coefficients:
##              Estimate Std. Error  t value Pr(>|t|)
## (Intercept) 18.805558   7.973540    2.358   0.0184 *
## depth       -1.615432   0.010819 -149.308   <2e-16 ***
## year4       -0.006318   0.003970   -1.591   0.1116
## daynum       0.074440   0.004125   18.047   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.522 on 9499 degrees of freedom
## Multiple R-squared:  0.7045, Adjusted R-squared:  0.7044
## F-statistic:  7549 on 3 and 9499 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: Given the results of the AIC step function, I used all of the explanatory variables (depth, year, and day number). This model also proves to be significant and thus we reject the null hypothosis and accept the alternative hypothosis. There is 9499 degrees of freedom and an adjusted R-squared value of 0.7044. This is an improvement over the previous model however it is not the most parsimoniuous which would need to be considered when choosing models.

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
temp_lake_anova<-aov(data=NTL_LTER3, temperature_C~lakename)
summary(temp_lake_anova)
```

```
##               Df Sum Sq Mean Sq F value Pr(>F)
```

```
## lakename       8  12019  1502.4   36.88 <2e-16 ***
## Residuals   9494 386708    40.7
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
temp_lake_lm<-lm(data=NTL_LTER3, temperature_C~lakename)
summary(temp_lake_lm)
```

```
##
## Call:
## lm(formula = temperature_C ~ lakename, data = NTL_LTER3)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -10.405  -5.358  -2.914   5.886  19.302
##
## Coefficients:
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)                 15.6992     0.5802  27.058  < 2e-16 ***
## lakenameCrampton Lake       -2.8291     0.6918  -4.090 4.36e-05 ***
## lakenameEast Long Lake      -6.5010     0.6169 -10.538  < 2e-16 ***
## lakenameHummingbird Lake    -6.7827     0.8428  -8.048 9.44e-16 ***
## lakenamePaul Lake           -4.0856     0.5935  -6.884 6.20e-12 ***
## lakenamePeter Lake          -4.5938     0.5926  -7.752 9.99e-15 ***
## lakenameTuesday Lake        -6.1413     0.6036 -10.174  < 2e-16 ***
## lakenameWard Lake           -2.5904     0.8139  -3.183  0.00146 **
## lakenameWest Long Lake      -5.3559     0.6124  -8.746  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 6.382 on 9494 degrees of freedom
## Multiple R-squared:  0.03014,    Adjusted R-squared:  0.02933
## F-statistic: 36.88 on 8 and 9494 DF,  p-value: < 2.2e-16
```

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

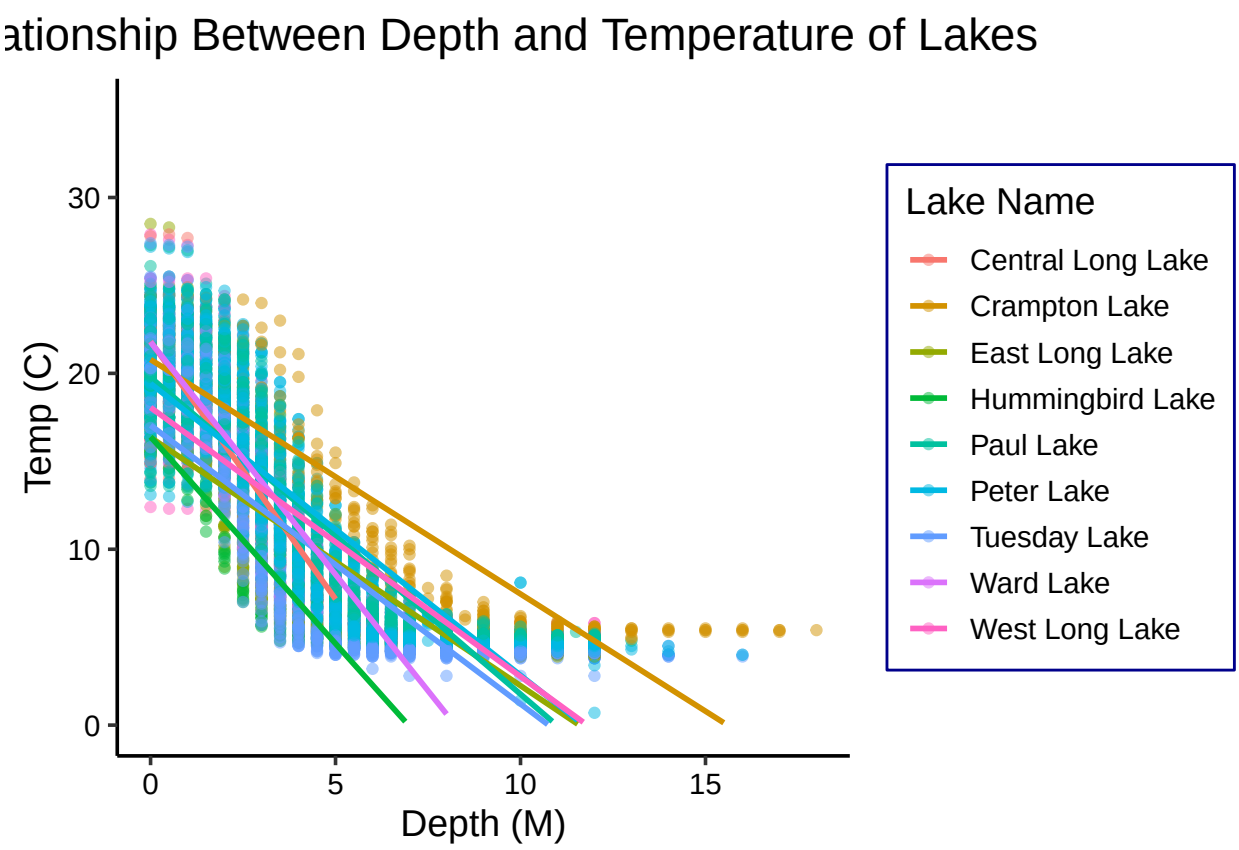
    Answer: There is a significant difference between mean temperatures among lakes. The anova test gave us a p value that is less than .05 so we would reject the null hypothesis and accept the alternative hypothesis that mean lake temperatures are different by lake. THe lm function also backs this up with a p value of less than .05.

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.
ggplot(NTL_LTER3, aes(x = depth, y = temperature_C, color = lakename))+
  geom_point(alpha = 0.5)+
  labs(title = "Relationship Between Depth and Temperature of Lakes", col = "Lake Name")+
  xlab("Depth (M)")+
  ylab("Temp (C)")+
  ylim(0,35)+
  geom_smooth(method="lm", se=FALSE)+
  mytheme
```

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

```
## Warning: Removed 88 rows containing missing values (geom_smooth).
```



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

```
#15
TukeyHSD(temp_lake_anova)
```

```
##   Tukey multiple comparisons of means
##     95% family-wise confidence level
##
## Fit: aov(formula = temperature_C ~ lakename, data = NTL_LTER3)
##
## $lakename
##                                       diff         lwr         upr     p adj
## Crampton Lake-Central Long Lake    -2.8291387 -4.97533050 -0.68294692 0.0014395
## East Long Lake-Central Long Lake   -6.5010074 -8.41491151 -4.58710334 0.0000000
## Hummingbird Lake-Central Long Lake -6.7826598 -9.39740915 -4.16791044 0.0000000
## Paul Lake-Central Long Lake        -4.0856227 -5.92698164 -2.24426374 0.0000000
## Peter Lake-Central Long Lake       -4.5938464 -6.43239794 -2.75529489 0.0000000
## Tuesday Lake-Central Long Lake     -6.1412824 -8.01392896 -4.26863584 0.0000000
## Ward Lake-Central Long Lake        -2.5903736 -5.11555124 -0.06519587 0.0392367
## West Long Lake-Central Long Lake   -5.3558591 -7.25566616 -3.45605194 0.0000000
## East Long Lake-Crampton Lake       -3.6718687 -5.00938971 -2.33434772 0.0000000
## Hummingbird Lake-Crampton Lake     -3.9535211 -6.18126607 -1.72577609 0.0000013
## Paul Lake-Crampton Lake            -1.2564840 -2.48796128 -0.02500667 0.0413505
## Peter Lake-Crampton Lake           -1.7647077 -2.99198326 -0.53743215 0.0002831
## Tuesday Lake-Crampton Lake         -3.3121437 -4.58993033 -2.03435704 0.0000000
```

```
## Ward Lake-Crampton Lake             0.2387652 -1.88313397  2.36066428 0.9999938
## West Long Lake-Crampton Lake       -2.5267203 -3.84399049 -1.20945020 0.0000001
## Hummingbird Lake-East Long Lake    -0.2816524 -2.28658065  1.72327592 0.9999656
## Paul Lake-East Long Lake            2.4153847  1.65813576  3.17263372 0.0000000
## Peter Lake-East Long Lake           1.9071610  1.15676448  2.65755754 0.0000000
## Tuesday Lake-East Long Lake         0.3597250 -0.47071364  1.19016370 0.9180513
## Ward Lake-East Long Lake            3.9106339  2.02401108  5.79725666 0.0000000
## West Long Lake-East Long Lake       1.1451484  0.25515383  2.03514292 0.0021540
## Paul Lake-Hummingbird Lake          2.6970371  0.76123976  4.63283444 0.0005285
## Peter Lake-Hummingbird Lake         2.1888134  0.25568630  4.12194045 0.0132248
## Tuesday Lake-Hummingbird Lake       0.6413774 -1.32420489  2.60695968 0.9848376
## Ward Lake-Hummingbird Lake          4.1922862  1.59743925  6.78713323 0.0000193
## West Long Lake-Hummingbird Lake     1.4268007 -0.56467500  3.41827648 0.3907140
## Peter Lake-Paul Lake               -0.5082237 -1.04736090  0.03091344 0.0830294
## Tuesday Lake-Paul Lake             -2.0556597 -2.70157171 -1.40974770 0.0000000
## Ward Lake-Paul Lake                 1.4952491 -0.31773721  3.30823548 0.2044231
## West Long Lake-Paul Lake           -1.2702364 -1.99111377 -0.54935896 0.0000017
## Tuesday Lake-Peter Lake            -1.5474360 -2.18530058 -0.90957138 0.0000000
## Ward Lake-Peter Lake                2.0034729  0.19333794  3.81360778 0.0173703
## West Long Lake-Peter Lake          -0.7620126 -1.47568845 -0.04833682 0.0259997
## Ward Lake-Tuesday Lake              3.5509088  1.70615361  5.39566407 0.0000001
## West Long Lake-Tuesday Lake         0.7854233 -0.01198909  1.58283578 0.0573522
## West Long Lake-Ward Lake           -2.7654855 -4.63780592 -0.89316507 0.0001611
```

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: According to the Tukey test, Paul lake has a the same mean temperature as Peter lake (statistically speaking). The p-value was greater than .05 which means we would accept our null hypothesis. It appears that Central Long Lake has has a mean temperature that is statistically distintc from all other lakes. All p-values with Cnetral Long Lake and other lakes are below .05.

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: We could use the function HSD test.