Assignment 6: 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. 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 setup
getwd()
```

```
## [1] "E:/ENV872/EDA-Fall2022"
```

```
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   1.2.1      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(corrplot)
```

```
## corrplot 0.92 loaded
```

```
library(ggplot2)
library(lubridate)
```

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

```
library(dplyr)

NTL.LTR.chem <- read.csv("./Data/Raw/NTL-LTER_Lake_ChemistryPhysics_Raw.csv", stringsAsFactors = TRUE)
head(NTL.LTR.chem)
```

```
##   lakeid  lakename year4 daynum sampledate depth temperature_C dissolvedOxygen
## 1      L Paul Lake  1984    148    5/27/84  0.00          14.5             9.5
## 2      L Paul Lake  1984    148    5/27/84  0.25            NA              NA
## 3      L Paul Lake  1984    148    5/27/84  0.50            NA              NA
## 4      L Paul Lake  1984    148    5/27/84  0.75            NA              NA
## 5      L Paul Lake  1984    148    5/27/84  1.00          14.5             8.8
## 6      L Paul Lake  1984    148    5/27/84  1.50            NA              NA
##   irradianceWater irradianceDeck comments
## 1            1750           1620     <NA>
## 2            1550           1620     <NA>
## 3            1150           1620     <NA>
## 4             975           1620     <NA>
## 5             870           1620     <NA>
## 6             610           1620     <NA>
```

```
NTL.LTR.chem$sampledate <- as.Date(NTL.LTR.chem$sampledate, format = "%m/%d/%y")
head(NTL.LTR.chem$sampledate)
```

```
## [1] "1984-05-27" "1984-05-27" "1984-05-27" "1984-05-27" "1984-05-27"
## [6] "1984-05-27"
```

```
# 2 set default theme
mytheme <- theme_classic(base_size = 14) + theme(axis.text = element_text(color = "black"),
    legend.position = "right")
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: the mean lake temperature recorded during July change with depth across all lakes Ha: the mean lake temperature recorded during July does not 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.

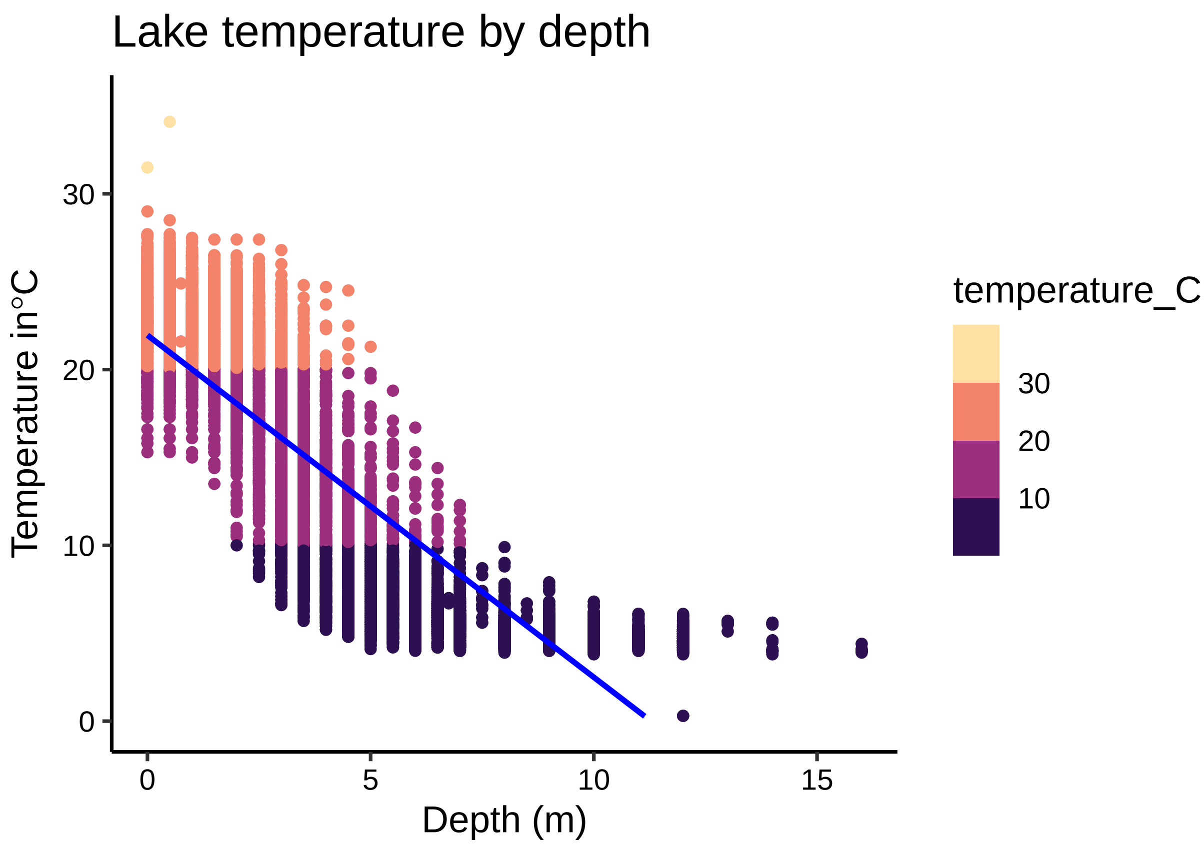
```
# 4 select NTL-LTR dataset
NTL.LTR.table <- NTL.LTR.chem %>%
    filter(month(sampledate) == 7) %>%
    select(lakename, year4, daynum, depth, temperature_C) %>%
    na.omit()
head(NTL.LTR.table)
```

```
##    lakename year4 daynum depth temperature_C
## 1 Paul Lake  1984    183   0.0          22.8
## 3 Paul Lake  1984    183   0.5          22.9
## 5 Paul Lake  1984    183   1.0          22.8
## 6 Paul Lake  1984    183   1.5          22.7
## 7 Paul Lake  1984    183   2.0          21.7
## 8 Paul Lake  1984    183   2.5          20.3
```

```
# 5 visualization of the relationship temperature by depth
ggplot(NTL.LTR.table, aes(x = depth, y = temperature_C)) + geom_point(aes(color = temperature_C)) +
    geom_smooth(method = "lm", color = "blue") + ylim(label = c(0, 35)) + ylab(expression("Temperature 
    degree * "C")) + xlab("Depth (m)") + scale_color_viridis_b(option = "magma") +
    ggtitle("Lake temperature by depth")
```

```
## `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 about anything about the linearity of this trend?

   Answer: The figure shows agreement to the null hypotesis with the mean of lake temperature recorded on July changes with depth across all lakes. The temperature change is inversely related to the depth, or the more depth will be the lower temperature. According to graph, the trend will mainly be linear, however, the trend will slope at a certain depth point or after 7 meters into about 4 to 10 Celcius degree.

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

```
# 7 Perform a linear regression
NTL.LTR.table.reg <- lm(data = NTL.LTR.table, temperature_C ~ depth)
summary(NTL.LTR.table.reg)
```

```
##
## Call:
## lm(formula = temperature_C ~ depth, data = NTL.LTR.table)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -9.5173 -3.0192  0.0633  2.9365 13.5834
##
## Coefficients:
```

```
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 21.95597    0.06792   323.3   <2e-16 ***
## depth       -1.94621    0.01174  -165.8   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.835 on 9726 degrees of freedom
## Multiple R-squared:  0.7387, Adjusted R-squared:  0.7387
## F-statistic: 2.75e+04 on 1 and 9726 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 both variable are inversely related. The temperature will decrease by 1.94 degree of Celcius as the depth increases by 1m. The finding is based on 1 and 9726 degrees of freedom. The statistics shows that about 74% of the variability in temperature is explained by the changes in depth of lake. The p-value is less than the level of significance with the Adjusted R-squared 0.7387.

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.

```r
# 9 Running an AIC
tempAIC <- lm(data = NTL.LTR.table, temperature_C ~ year4 + daynum + depth)
step(tempAIC)
```

```
## Start:  AIC=26065.53
## temperature_C ~ year4 + daynum + depth
##
##          Df Sum of Sq    RSS   AIC
## <none>                141687 26066
## - year4   1       101 141788 26070
## - daynum  1      1237 142924 26148
## - depth   1    404475 546161 39189

##
## Call:
## lm(formula = temperature_C ~ year4 + daynum + depth, data = NTL.LTR.table)
##
## Coefficients:
## (Intercept)        year4       daynum        depth
##    -8.57556      0.01134      0.03978     -1.94644
```

```r
# 10 Running a multiple regression
Temp.multiregress <- lm(data = NTL.LTR.table, temperature_C ~ year4 + daynum + depth)
summary(Temp.multiregress)
```

```
##
## Call:
## lm(formula = temperature_C ~ year4 + daynum + depth, data = NTL.LTR.table)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -9.6536 -3.0000  0.0902  2.9658 13.6123
##
## Coefficients:
##              Estimate Std. Error  t value Pr(>|t|)
## (Intercept) -8.575564   8.630715   -0.994  0.32044
## year4        0.011345   0.004299    2.639  0.00833 **
## daynum       0.039780   0.004317    9.215  < 2e-16 ***
## depth       -1.946437   0.011683 -166.611  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.817 on 9724 degrees of freedom
## Multiple R-squared:  0.7412, Adjusted R-squared:  0.7411
## F-statistic:  9283 on 3 and 9724 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 suggest year4, daynum and depth as the set of explanatory variable to predict temperature in the multiple regression. However, this model explains 74.12% of the observed variance in the lake temperature.Therefore, there is a slight improvement of the model that use depth only as 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).

```r
# 12 an ANOVA models to see the different lakes with different temperatures on
# July
lake.temp.anova <- aov(data = NTL.LTR.table, temperature_C ~ lakename)
summary(lake.temp.anova)
```

```
##               Df Sum Sq Mean Sq F value Pr(>F)
## lakename       8  21642  2705.2      50 <2e-16 ***
## Residuals   9719 525813    54.1
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# a linear model to see the different lakes with different temperatures on July
lake.temp.lm <- lm(data = NTL.LTR.table, temperature_C ~ lakename)
summary(lake.temp.lm)
```

```
##
## Call:
## lm(formula = temperature_C ~ lakename, data = NTL.LTR.table)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -10.769  -6.614  -2.679   7.684  23.832
##
## Coefficients:
##                          Estimate Std. Error t value Pr(>|t|)
## (Intercept)               17.6664     0.6501  27.174  < 2e-16 ***
## lakenameCrampton Lake     -2.3145     0.7699  -3.006 0.002653 **
## lakenameEast Long Lake    -7.3987     0.6918 -10.695  < 2e-16 ***
## lakenameHummingbird Lake  -6.8931     0.9429  -7.311 2.87e-13 ***
## lakenamePaul Lake         -3.8522     0.6656  -5.788 7.36e-09 ***
## lakenamePeter Lake        -4.3501     0.6645  -6.547 6.17e-11 ***
## lakenameTuesday Lake      -6.5972     0.6769  -9.746  < 2e-16 ***
## lakenameWard Lake         -3.2078     0.9429  -3.402 0.000672 ***
## lakenameWest Long Lake    -6.0878     0.6895  -8.829  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 7.355 on 9719 degrees of freedom
## Multiple R-squared:  0.03953,    Adjusted R-squared:  0.03874
## F-statistic:    50 on 8 and 9719 DF,  p-value: < 2.2e-16
```

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

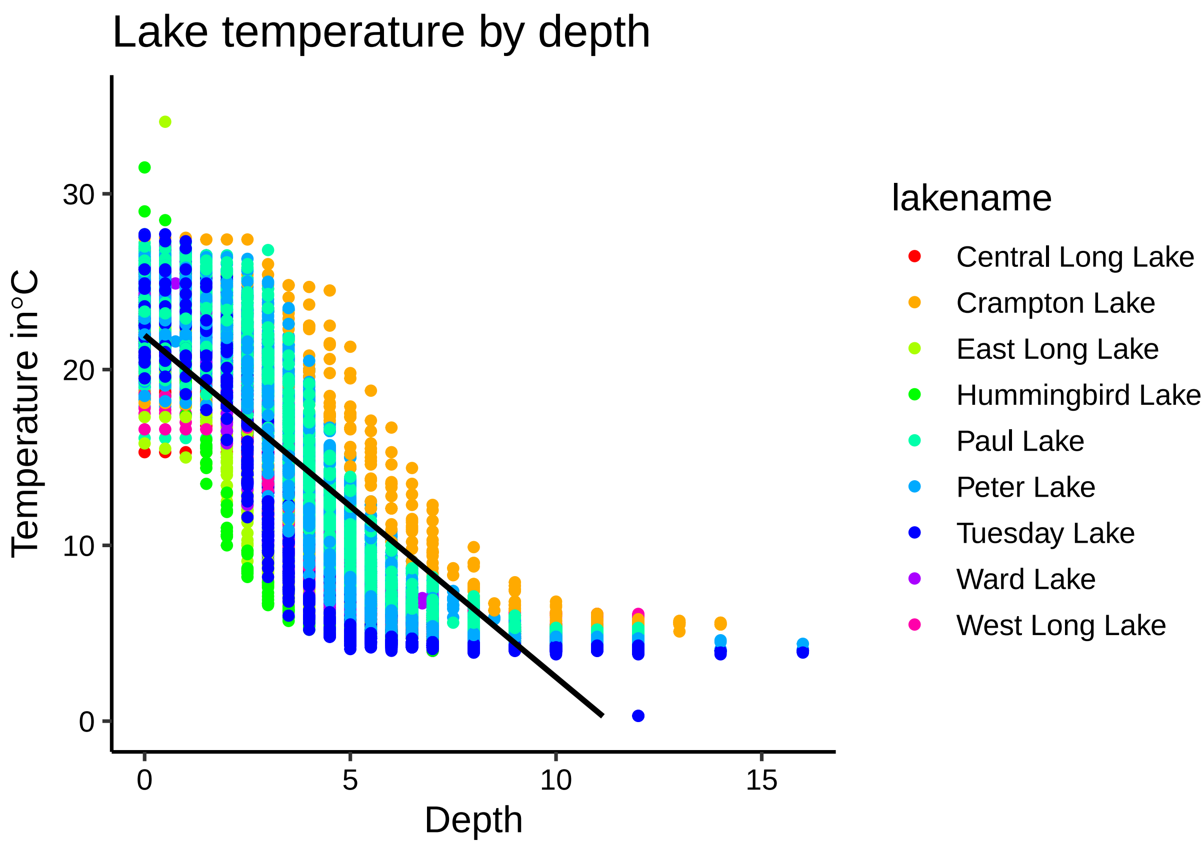
    Answer: Both ANOVA and linear models, they don't have a significant difference in mean temperature or mean value. In addition, we also can see that it has p-values with less than the significance level (alpha = 0.05) which is important in determining the decision to reject null hypothesis.

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.

```r
# 14. Scatterplot graph temperature by depth
ggplot(NTL.LTR.table, aes(x = depth, y = temperature_C)) + geom_point(aes(color = lakename)) +
    geom_smooth(method = "lm", se = FALSE, alpha = 0.5, color = "black") + ylim(0,
    35) + ylab(expression("Temperature in" * degree * "C")) + xlab("Depth") + scale_color_manual(values
    ggtitle("Lake temperature by depth")
```

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

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



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

```
# 15 Post-hoc test using Tukey Honest Significant Differences
TukeyHSD(lake.temp.anova)
```

```
##   Tukey multiple comparisons of means
##     95% family-wise confidence level
##
## Fit: aov(formula = temperature_C ~ lakename, data = NTL.LTR.table)
##
## $lakename
##                                        diff        lwr        upr     p adj
## Crampton Lake-Central Long Lake    -2.3145195 -4.7031913  0.0741524 0.0661566
## East Long Lake-Central Long Lake   -7.3987410 -9.5449411 -5.2525408 0.0000000
## Hummingbird Lake-Central Long Lake -6.8931304 -9.8184178 -3.9678430 0.0000000
## Paul Lake-Central Long Lake        -3.8521506 -5.9170942 -1.7872070 0.0000003
## Peter Lake-Central Long Lake       -4.3501458 -6.4115874 -2.2887042 0.0000000
## Tuesday Lake-Central Long Lake     -6.5971805 -8.6971605 -4.4972005 0.0000000
## Ward Lake-Central Long Lake        -3.2077856 -6.1330730 -0.2824982 0.0193405
## West Long Lake-Central Long Lake   -6.0877513 -8.2268550 -3.9486475 0.0000000
## East Long Lake-Crampton Lake       -5.0842215 -6.5591700 -3.6092730 0.0000000
## Hummingbird Lake-Crampton Lake     -4.5786109 -7.0538088 -2.1034131 0.0000004
## Paul Lake-Crampton Lake            -1.5376312 -2.8916215 -0.1836408 0.0127491
## Peter Lake-Crampton Lake           -2.0356263 -3.3842699 -0.6869828 0.0000999
## Tuesday Lake-Crampton Lake         -4.2826611 -5.6895065 -2.8758157 0.0000000
```

```
## Ward Lake-Crampton Lake            -0.8932661 -3.3684639  1.5819317 0.9714459
## West Long Lake-Crampton Lake       -3.7732318 -5.2378351 -2.3086285 0.0000000
## Hummingbird Lake-East Long Lake     0.5056106 -1.7364925  2.7477137 0.9988050
## Paul Lake-East Long Lake            3.5465903  2.6900206  4.4031601 0.0000000
## Peter Lake-East Long Lake           3.0485952  2.2005025  3.8966879 0.0000000
## Tuesday Lake-East Long Lake         0.8015604 -0.1363286  1.7394495 0.1657485
## Ward Lake-East Long Lake            4.1909554  1.9488523  6.4330585 0.0000002
## West Long Lake-East Long Lake       1.3109897  0.2885003  2.3334791 0.0022805
## Paul Lake-Hummingbird Lake          3.0409798  0.8765299  5.2054296 0.0004495
## Peter Lake-Hummingbird Lake         2.5429846  0.3818755  4.7040937 0.0080666
## Tuesday Lake-Hummingbird Lake       0.2959499 -1.9019508  2.4938505 0.9999752
## Ward Lake-Hummingbird Lake          3.6853448  0.6889874  6.6817022 0.0043297
## West Long Lake-Hummingbird Lake     0.8053791 -1.4299320  3.0406903 0.9717297
## Peter Lake-Paul Lake               -0.4979952 -1.1120620  0.1160717 0.2241586
## Tuesday Lake-Paul Lake             -2.7450299 -3.4781416 -2.0119182 0.0000000
## Ward Lake-Paul Lake                 0.6443651 -1.5200848  2.8088149 0.9916978
## West Long Lake-Paul Lake           -2.2356007 -3.0742314 -1.3969699 0.0000000
## Tuesday Lake-Peter Lake            -2.2470347 -2.9702236 -1.5238458 0.0000000
## Ward Lake-Peter Lake                1.1423602 -1.0187489  3.3034693 0.7827037
## West Long Lake-Peter Lake          -1.7376055 -2.5675759 -0.9076350 0.0000000
## Ward Lake-Tuesday Lake              3.3893950  1.1914943  5.5872956 0.0000609
## West Long Lake-Tuesday Lake         0.5094292 -0.4121051  1.4309636 0.7374387
## West Long Lake-Ward Lake           -2.8799657 -5.1152769 -0.6446546 0.0021080
```

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: Paul lake and Ward lake, statistically speaking, are the lakes with the same mean temperature as Peter lake. There is no lake has a mean temperature that is significantly distinct from the other lakes.

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: Another test that could be used is the two-sample t-test to compare the distinction of mean temperature between two lakes.

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 select Crampton Lake and Ward Lake dataset on July
NTL.LTR.cramptonWard <- NTL.LTR.chem %>%
    filter(month(sampledate) == 7, lakename %in% c("Crampton Lake", "Ward Lake")) %>%
    select(lakename, year4, daynum, depth, temperature_C) %>%
    na.omit()

# Format as a t-test
NTL.LTR.cramptonWard.twosample <- t.test(NTL.LTR.cramptonWard$temperature_C ~ NTL.LTR.cramptonWard$laker
NTL.LTR.cramptonWard.twosample
```

```
##
##  Welch Two Sample t-test
##
## data:  NTL.LTR.cramptonWard$temperature_C by NTL.LTR.cramptonWard$lakename
## t = 1.1181, df = 200.37, p-value = 0.2649
## alternative hypothesis: true difference in means between group Crampton Lake and group Ward Lake is r
## 95 percent confidence interval:
##  -0.6821129  2.4686451
## sample estimates:
## mean in group Crampton Lake     mean in group Ward Lake
##                    15.35189                    14.45862
```

```
# Format as a GLM
NTL.LTR.cramptonWard.twosample2 <- lm(NTL.LTR.cramptonWard$temperature_C ~ NTL.LTR.cramptonWard$lakename
summary(NTL.LTR.cramptonWard.twosample2)
```

```
##
## Call:
## lm(formula = NTL.LTR.cramptonWard$temperature_C ~ NTL.LTR.cramptonWard$lakename)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -10.3519  -7.5286   0.1947   7.0481  13.1414
##
## Coefficients:
##                                        Estimate Std. Error t value Pr(>|t|)
## (Intercept)                             15.3519     0.4087   37.56   <2e-16 ***
## NTL.LTR.cramptonWard$lakenameWard Lake  -0.8933     0.7906   -1.13    0.259
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 7.289 on 432 degrees of freedom
## Multiple R-squared:  0.002946,   Adjusted R-squared:  0.0006383
## F-statistic: 1.277 on 1 and 432 DF,  p-value: 0.2592
```

Answer: The two-sample T-test shows a difference on temperature for both Lakes. It is not equal as the mean difference value is around 0.9. This data reveals that it is not in line with the above data at part 16.