

# 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. 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.

```
## My document will not knit without this code
```

```
knitr::opts_knit$set(root.dir = '/Users/analyselindborg/Desktop/Desktop - Analise's MacBook Pro/Data Analytics/Environmental_Data_Analysis')
```

## 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] "/Users/analyselindborg/Desktop/Desktop - Analise's MacBook Pro/Data Analytics/Environmental_Data_Analysis"
```

```
library(tidyverse)
```

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

```
## v ggplot2 3.3.3      v purrr  0.3.4
```

```
## v tibble  3.0.5      v dplyr  1.0.3
```

```
## v tidyr   1.1.2      v stringr 1.4.0
```

```
## v readr   1.4.0      v forcats 0.5.0
```

```
## -- Conflicts ----- tidyverse_conflicts() --
```

```
## x dplyr::filter() masks stats::filter()
```

```
## x dplyr::lag()    masks stats::lag()
```

```
library(agricolae)
```

```
library(lubridate)
```

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

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

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

lake.chem$sampldate <- as.Date(lake.chem$sampldate, format = "%m/%d/%y")

#2
theme <-
  theme_bw() +
  theme(panel.grid.minor = element_blank(),
        text = element_text(color = "black", size = 10),
        axis.text.x = element_text(color = "black"),
        axis.text.y = element_text(color = "black"))

theme_set(theme)
```

## Simple regression

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

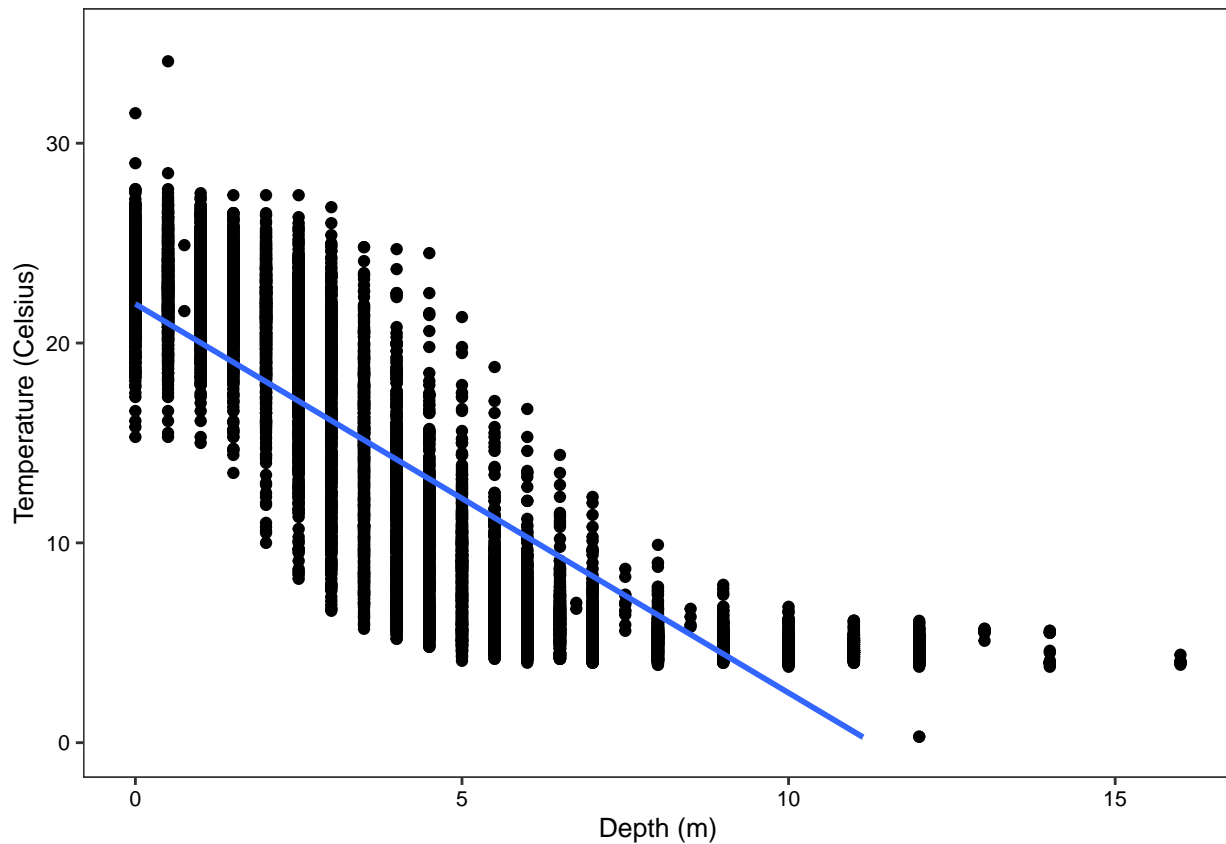
3. State the null and alternative hypotheses for this question: > Answer: H0: Mean lake temperature in July does not change with depth across lakes Ha: Mean lake temperature in July does change with depth across lakes
4. Wrangle your NTL-LTER dataset with a pipe function so that the records meet the 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
lake.chem.sub <- lake.chem %>%
  mutate(month = month(sampldate)) %>%
  filter(month == 7) %>%
  select(lakename, year4, daynum, depth, temperature_C) %>%
  filter(!is.na(temperature_C))

#5
ggplot(lake.chem.sub, aes(x = depth, y = temperature_C)) +
  geom_point() +
  geom_smooth(method = "lm") +
  ylim(0,35) +
  labs(x = "Depth (m)", y = "Temperature (Celsius)") +
  theme +
  theme(panel.grid.major = element_blank())

## `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: Temperature decreases with increasing depth. Based on the regression line, there is a negative linear relationship between temperature and depth. There is more temperature variability in the shallower depths.

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

```
#7
depth.temp.reg <- lm(lake.chem.sub$depth ~ lake.chem.sub$temperature_C)
summary(depth.temp.reg)
```

```
##
## Call:
## lm(formula = lake.chem.sub$depth ~ lake.chem.sub$temperature_C)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -4.0685 -1.1065 -0.2334  0.9668  8.0964
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    9.573728   0.033803   283.2   <2e-16 ***
## lake.chem.sub$temperature_C -0.379578   0.002289  -165.8   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
## Residual standard error: 1.694 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: There is a significant negative correlation between lake temperature and depth when tested for all lakes (df = 9,2726). 74% of the variability in temperature can be explained by changes in depth.

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## 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
temp.AIC <- lm(data = lake.chem.sub, temperature_C ~ year4 + daynum
               + depth)
step(temp.AIC)

## 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 = lake.chem.sub)
##
## Coefficients:
## (Intercept)      year4      daynum      depth
##   -8.57556      0.01134      0.03978     -1.94644
```

```
#10
temp.lm <- lm(data = lake.chem.sub, temperature_C ~ year4 + daynum
              + depth)
summary(temp.lm)
```

```
##
## Call:
## lm(formula = temperature_C ~ year4 + daynum + depth, data = lake.chem.sub)
##
## 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 suggests using all input explanatory variables (year4, dpeth, and daynum). This model explains 74% of the variance in temperature. It is not an improvement over the model using only depth because we are not increasing our adjusted R-squared value and adding more variables takes away degrees of freedom (introduces more unceratinty).

---

## 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.aov <- aov(data=lake.chem.sub, temperature_C ~ lakename)
summary(temp.lake.aov)
```

```
##           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
```

```
temp.lake.lm <- lm(data=lake.chem.sub, temperature_C ~ lakename)
summary(temp.lake.lm)
```

```
##
## Call:
## lm(formula = temperature_C ~ lakename, data = lake.chem.sub)
##
## 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
```

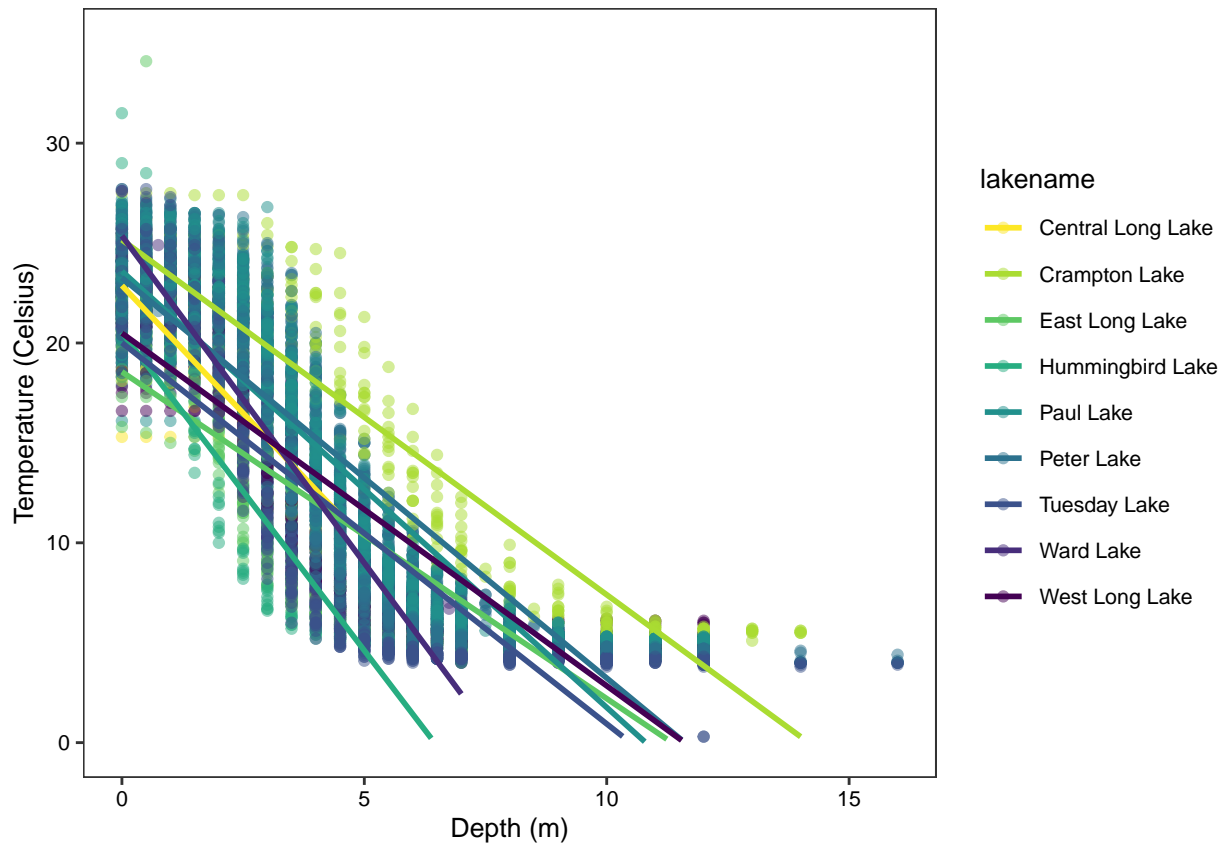
13. Is there a significant difference in mean temperature among the lakes? Report your findings.

Answer: There is a significant difference in mean temperature among the different lakes in July (ANOVA p-value < 2e-16).

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(lake.chem.sub, aes(x = depth, y = temperature_C, color = lakename)) +
  geom_point(alpha = 0.5) +
  geom_smooth(method = "lm", se = FALSE) +
  ylim(0,35) +
  scale_color_viridis_d(begin = 1, end = 0) +
  labs(x = "Depth (m)", y = "Temperature (Celsius)") +
  theme +
  theme(panel.grid.major = element_blank())

## `geom_smooth()` using formula 'y ~ x'
## Warning: Removed 73 rows containing missing values (geom_smooth).
```



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

#15

```
TukeyHSD(temp.lake.aov)
```

```
## Tukey multiple comparisons of means
## 95% family-wise confidence level
##
## Fit: aov(formula = temperature_C ~ lakename, data = lake.chem.sub)
##
## $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 mean temperatures do not differ significantly from Peter Lake in July. None of the lakes have a mean temperature that is statistically different from all 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: A two-sample t-test could also tell you the statistical difference between two means (such as mean temperature difference between Peter and Paul Lake)