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 Monday, February 28 at 7:00 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.

```
#1

getwd()
```

```
## [1] "C:/Users/gabri/OneDrive/Desktop/MPP Coursework/Spring 2022/ENVIRO 872/Environmental_Data_Analyti
```

```
library(tidyverse)
```

```
## -- Attaching packages --------------------------------------- tidyverse 1.3.1 --
```

```
## v ggplot2 3.3.5     v purrr   0.3.4
## v tibble  3.1.6     v dplyr   1.0.7
## v tidyr   1.1.4     v stringr 1.4.0
## v readr   2.1.1     v forcats 0.5.1
```

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

```r
library(corrplot)
```

```
## corrplot 0.92 loaded
```

```r
library(agricolae)

NTL_LTER_Lake_ChemistryPhysics_Raw <- read_csv("../Data/Raw/NTL-LTER_Lake_ChemistryPhysics_Raw.csv")
```

```
## Rows: 38614 Columns: 11
```

```
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## chr (4): lakeid, lakename, sampledate, comments
## dbl (7): year4, daynum, depth, temperature_C, dissolvedOxygen, irradianceWat...
##
## i Use 'spec()' to retrieve the full column specification for this data.
## i Specify the column types or set 'show_col_types = FALSE' to quiet this message.
```

```r
NTL_LTER_Lake_ChemistryPhysics_Raw$sampledate <- as.Date( NTL_LTER_Lake_ChemistryPhysics_Raw$sampledat

class(NTL_LTER_Lake_ChemistryPhysics_Raw$sampledate)
```

```
## [1] "Date"
```

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

```r
#2

mytheme <- theme_classic(base_size = 12) +
theme(axis.text = element_text(color = "black"),
legend.position = "right")
theme_set(mytheme)
theme_get()
```

```
## List of 93
##  $ line                     :List of 6
##   ..$ colour       : chr "black"
##   ..$ size         : num 0.545
##   ..$ linetype     : num 1
##   ..$ lineend      : chr "butt"
##   ..$ arrow        : logi FALSE
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_line" "element"
##  $ rect                     :List of 5
##   ..$ fill         : chr "white"
##   ..$ colour       : chr "black"
##   ..$ size         : num 0.545
##   ..$ linetype     : num 1
##   ..$ inherit.blank: logi TRUE
```

```
##   ..- attr(*, "class")= chr [1:2] "element_rect" "element"
## $ text                     :List of 11
##   ..$ family      : chr ""
##   ..$ face        : chr "plain"
##   ..$ colour      : chr "black"
##   ..$ size        : num 12
##   ..$ hjust       : num 0.5
##   ..$ vjust       : num 0.5
##   ..$ angle       : num 0
##   ..$ lineheight  : num 0.9
##   ..$ margin      : 'margin' num [1:4] 0points 0points 0points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug       : logi FALSE
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ title                    : NULL
## $ aspect.ratio             : NULL
## $ axis.title               : NULL
## $ axis.title.x             :List of 11
##   ..$ family      : NULL
##   ..$ face        : NULL
##   ..$ colour      : NULL
##   ..$ size        : NULL
##   ..$ hjust       : NULL
##   ..$ vjust       : num 1
##   ..$ angle       : NULL
##   ..$ lineheight  : NULL
##   ..$ margin      : 'margin' num [1:4] 3points 0points 0points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug       : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ axis.title.x.top         :List of 11
##   ..$ family      : NULL
##   ..$ face        : NULL
##   ..$ colour      : NULL
##   ..$ size        : NULL
##   ..$ hjust       : NULL
##   ..$ vjust       : num 0
##   ..$ angle       : NULL
##   ..$ lineheight  : NULL
##   ..$ margin      : 'margin' num [1:4] 0points 0points 3points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug       : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ axis.title.x.bottom      : NULL
## $ axis.title.y             :List of 11
##   ..$ family      : NULL
##   ..$ face        : NULL
##   ..$ colour      : NULL
##   ..$ size        : NULL
##   ..$ hjust       : NULL
##   ..$ vjust       : num 1
```

```
##   ..$ angle       : num 90
##   ..$ lineheight  : NULL
##   ..$ margin      : 'margin' num [1:4] 0points 3points 0points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug       : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ axis.title.y.left       : NULL
## $ axis.title.y.right      :List of 11
##   ..$ family      : NULL
##   ..$ face        : NULL
##   ..$ colour      : NULL
##   ..$ size        : NULL
##   ..$ hjust       : NULL
##   ..$ vjust       : num 0
##   ..$ angle       : num -90
##   ..$ lineheight  : NULL
##   ..$ margin      : 'margin' num [1:4] 0points 0points 0points 3points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug       : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ axis.text               :List of 11
##   ..$ family      : NULL
##   ..$ face        : NULL
##   ..$ colour      : chr "black"
##   ..$ size        : 'rel' num 0.8
##   ..$ hjust       : NULL
##   ..$ vjust       : NULL
##   ..$ angle       : NULL
##   ..$ lineheight  : NULL
##   ..$ margin      : NULL
##   ..$ debug       : NULL
##   ..$ inherit.blank: logi FALSE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ axis.text.x             :List of 11
##   ..$ family      : NULL
##   ..$ face        : NULL
##   ..$ colour      : NULL
##   ..$ size        : NULL
##   ..$ hjust       : NULL
##   ..$ vjust       : num 1
##   ..$ angle       : NULL
##   ..$ lineheight  : NULL
##   ..$ margin      : 'margin' num [1:4] 2.4points 0points 0points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug       : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ axis.text.x.top         :List of 11
##   ..$ family      : NULL
##   ..$ face        : NULL
##   ..$ colour      : NULL
##   ..$ size        : NULL
```

```
##   ..$ hjust       : NULL
##   ..$ vjust       : num 0
##   ..$ angle       : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 0points 0points 2.4points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ axis.text.x.bottom        : NULL
## $ axis.text.y               :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : num 1
##   ..$ vjust        : NULL
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 0points 2.4points 0points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ axis.text.y.left          : NULL
## $ axis.text.y.right         :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : num 0
##   ..$ vjust        : NULL
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 0points 0points 0points 2.4points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ axis.ticks                :List of 6
##   ..$ colour       : chr "grey20"
##   ..$ size         : NULL
##   ..$ linetype     : NULL
##   ..$ lineend      : NULL
##   ..$ arrow        : logi FALSE
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_line" "element"
## $ axis.ticks.x              : NULL
## $ axis.ticks.x.top          : NULL
## $ axis.ticks.x.bottom       : NULL
## $ axis.ticks.y              : NULL
## $ axis.ticks.y.left         : NULL
## $ axis.ticks.y.right        : NULL
## $ axis.ticks.length        : 'simpleUnit' num 3points
```

```
##   ..- attr(*, "unit")= int 8
## $ axis.ticks.length.x        : NULL
## $ axis.ticks.length.x.top    : NULL
## $ axis.ticks.length.x.bottom: NULL
## $ axis.ticks.length.y        : NULL
## $ axis.ticks.length.y.left   : NULL
## $ axis.ticks.length.y.right  : NULL
## $ axis.line                  :List of 6
##   ..$ colour     : chr "black"
##   ..$ size       : 'rel' num 1
##   ..$ linetype   : NULL
##   ..$ lineend    : NULL
##   ..$ arrow      : logi FALSE
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_line" "element"
## $ axis.line.x                : NULL
## $ axis.line.x.top            : NULL
## $ axis.line.x.bottom         : NULL
## $ axis.line.y                : NULL
## $ axis.line.y.left           : NULL
## $ axis.line.y.right          : NULL
## $ legend.background          :List of 5
##   ..$ fill       : NULL
##   ..$ colour     : logi NA
##   ..$ size       : NULL
##   ..$ linetype   : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_rect" "element"
## $ legend.margin              : 'margin' num [1:4] 6points 6points 6points 6points
##   ..- attr(*, "unit")= int 8
## $ legend.spacing             : 'simpleUnit' num 12points
##   ..- attr(*, "unit")= int 8
## $ legend.spacing.x           : NULL
## $ legend.spacing.y           : NULL
## $ legend.key                 : list()
##   ..- attr(*, "class")= chr [1:2] "element_blank" "element"
## $ legend.key.size            : 'simpleUnit' num 1.2lines
##   ..- attr(*, "unit")= int 3
## $ legend.key.height          : NULL
## $ legend.key.width           : NULL
## $ legend.text                :List of 11
##   ..$ family     : NULL
##   ..$ face       : NULL
##   ..$ colour     : NULL
##   ..$ size       : 'rel' num 0.8
##   ..$ hjust      : NULL
##   ..$ vjust      : NULL
##   ..$ angle      : NULL
##   ..$ lineheight : NULL
##   ..$ margin     : NULL
##   ..$ debug      : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
## $ legend.text.align          : NULL
```

```
##  $ legend.title                 :List of 11
##   ..$ family        : NULL
##   ..$ face          : NULL
##   ..$ colour        : NULL
##   ..$ size          : NULL
##   ..$ hjust         : num 0
##   ..$ vjust         : NULL
##   ..$ angle         : NULL
##   ..$ lineheight    : NULL
##   ..$ margin        : NULL
##   ..$ debug         : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ legend.title.align        : NULL
##  $ legend.position           : chr "right"
##  $ legend.direction          : NULL
##  $ legend.justification      : chr "center"
##  $ legend.box                : NULL
##  $ legend.box.just           : NULL
##  $ legend.box.margin         : 'margin' num [1:4] 0cm 0cm 0cm 0cm
##   ..- attr(*, "unit")= int 1
##  $ legend.box.background      : list()
##   ..- attr(*, "class")= chr [1:2] "element_blank" "element"
##  $ legend.box.spacing         : 'simpleUnit' num 12points
##   ..- attr(*, "unit")= int 8
##  $ panel.background           :List of 5
##   ..$ fill          : chr "white"
##   ..$ colour        : logi NA
##   ..$ size          : NULL
##   ..$ linetype      : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_rect" "element"
##  $ panel.border              : list()
##   ..- attr(*, "class")= chr [1:2] "element_blank" "element"
##  $ panel.spacing             : 'simpleUnit' num 6points
##   ..- attr(*, "unit")= int 8
##  $ panel.spacing.x           : NULL
##  $ panel.spacing.y           : NULL
##  $ panel.grid                :List of 6
##   ..$ colour        : chr "grey92"
##   ..$ size          : NULL
##   ..$ linetype      : NULL
##   ..$ lineend       : NULL
##   ..$ arrow         : logi FALSE
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_line" "element"
##  $ panel.grid.major          : list()
##   ..- attr(*, "class")= chr [1:2] "element_blank" "element"
##  $ panel.grid.minor          : list()
##   ..- attr(*, "class")= chr [1:2] "element_blank" "element"
##  $ panel.grid.major.x        : NULL
##  $ panel.grid.major.y        : NULL
##  $ panel.grid.minor.x        : NULL
##  $ panel.grid.minor.y        : NULL
```

```
##  $ panel.ontop              : logi FALSE
##  $ plot.background          :List of 5
##   ..$ fill        : NULL
##   ..$ colour      : chr "white"
##   ..$ size        : NULL
##   ..$ linetype    : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_rect" "element"
##  $ plot.title               :List of 11
##   ..$ family      : NULL
##   ..$ face        : NULL
##   ..$ colour      : NULL
##   ..$ size        : 'rel' num 1.2
##   ..$ hjust       : num 0
##   ..$ vjust       : num 1
##   ..$ angle       : NULL
##   ..$ lineheight  : NULL
##   ..$ margin      : 'margin' num [1:4] 0points 0points 6points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug       : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ plot.title.position      : chr "panel"
##  $ plot.subtitle            :List of 11
##   ..$ family      : NULL
##   ..$ face        : NULL
##   ..$ colour      : NULL
##   ..$ size        : NULL
##   ..$ hjust       : num 0
##   ..$ vjust       : num 1
##   ..$ angle       : NULL
##   ..$ lineheight  : NULL
##   ..$ margin      : 'margin' num [1:4] 0points 0points 6points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug       : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ plot.caption             :List of 11
##   ..$ family      : NULL
##   ..$ face        : NULL
##   ..$ colour      : NULL
##   ..$ size        : 'rel' num 0.8
##   ..$ hjust       : num 1
##   ..$ vjust       : num 1
##   ..$ angle       : NULL
##   ..$ lineheight  : NULL
##   ..$ margin      : 'margin' num [1:4] 6points 0points 0points 0points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug       : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ plot.caption.position    : chr "panel"
##  $ plot.tag                 :List of 11
##   ..$ family      : NULL
```

```
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : 'rel' num 1.2
##   ..$ hjust        : num 0.5
##   ..$ vjust        : num 0.5
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : NULL
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ plot.tag.position       : chr "topleft"
##  $ plot.margin             : 'margin' num [1:4] 6points 6points 6points 6points
##   ..- attr(*, "unit")= int 8
##  $ strip.background        :List of 5
##   ..$ fill         : chr "white"
##   ..$ colour       : chr "black"
##   ..$ size         : 'rel' num 2
##   ..$ linetype     : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_rect" "element"
##  $ strip.background.x      : NULL
##  $ strip.background.y      : NULL
##  $ strip.placement         : chr "inside"
##  $ strip.text              :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : chr "grey10"
##   ..$ size         : 'rel' num 0.8
##   ..$ hjust        : NULL
##   ..$ vjust        : NULL
##   ..$ angle        : NULL
##   ..$ lineheight   : NULL
##   ..$ margin       : 'margin' num [1:4] 4.8points 4.8points 4.8points 4.8points
##   .. ..- attr(*, "unit")= int 8
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ strip.text.x            : NULL
##  $ strip.text.y            :List of 11
##   ..$ family       : NULL
##   ..$ face         : NULL
##   ..$ colour       : NULL
##   ..$ size         : NULL
##   ..$ hjust        : NULL
##   ..$ vjust        : NULL
##   ..$ angle        : num -90
##   ..$ lineheight   : NULL
##   ..$ margin       : NULL
##   ..$ debug        : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  $ strip.switch.pad.grid   : 'simpleUnit' num 3points
##   ..- attr(*, "unit")= int 8
```

```
##  $ strip.switch.pad.wrap     : 'simpleUnit' num 3points
##   ..- attr(*, "unit")= int 8
##  $ strip.text.y.left         :List of 11
##   ..$ family      : NULL
##   ..$ face        : NULL
##   ..$ colour      : NULL
##   ..$ size        : NULL
##   ..$ hjust       : NULL
##   ..$ vjust       : NULL
##   ..$ angle       : num 90
##   ..$ lineheight  : NULL
##   ..$ margin      : NULL
##   ..$ debug       : NULL
##   ..$ inherit.blank: logi TRUE
##   ..- attr(*, "class")= chr [1:2] "element_text" "element"
##  - attr(*, "class")= chr [1:2] "theme" "gg"
##  - attr(*, "complete")= logi TRUE
##  - attr(*, "validate")= logi TRUE
```

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: mu = 0 Ha: mu != 0

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)

```
#4
```

```
library(lubridate)
```

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

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

```
NTL_LTER_subset <-
  NTL_LTER_Lake_ChemistryPhysics_Raw %>%
  filter(month(sampledate) == 7) %>%
  select(lakename, year4, daynum, depth, temperature_C)%>%
  na.omit()
```

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.

```
#5
library(viridis)
```

Loading required package: viridisLite

```
NTL_LTER_scatterplot <- ggplot(NTL_LTER_subset,
  aes(x = depth, y= temperature_C, color=temperature_C)) +
  geom_point() +
  scale_color_viridis(option = "magma")+
  ylim(0,35) +
  ylab("Temperature in Celsius") +
  xlab("Depth (m)") +
  labs(color = "Temperature")+
  geom_smooth(method = 'lm', se = TRUE, color = "blue")

print(NTL_LTER_scatterplot)
```

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

Warning: Removed 24 rows containing missing values (geom_smooth).
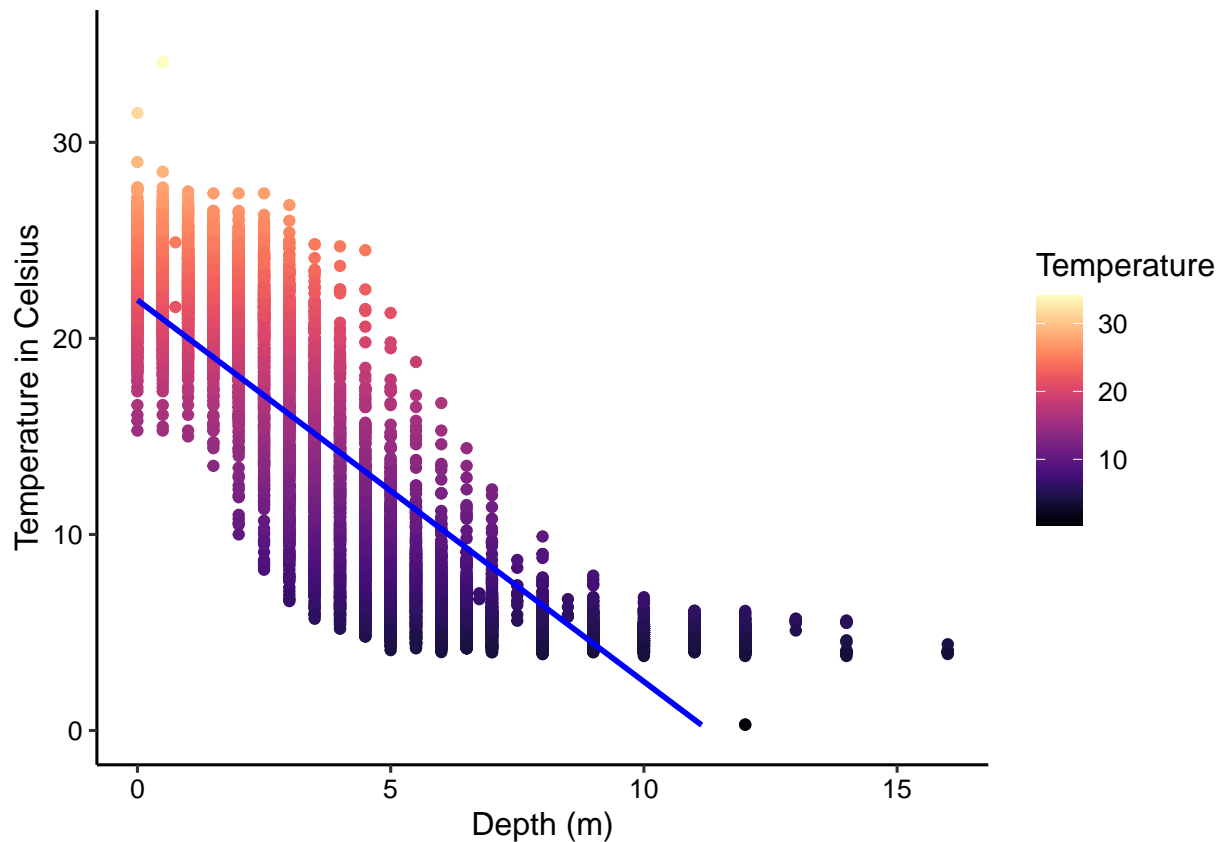
6. Interpret the figure. What does it suggest with regards to the response of temperature to depth? Do the distribution of points suggest about anything about the linearity of this trend?

Answer: As depth increases, temperature decreases until you get to around 7 meters. Then, temperature stays relatively constant around 8 degrees Celsius. The relationship is not linear at that point. The relationship appears inverse.

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

```
#7

DepthTempRegression <- lm(data=NTL_LTER_subset, temperature_C ~ depth)
summary(DepthTempRegression)
```

```
##
## Call:
## lm(formula = temperature_C ~ depth, data = NTL_LTER_subset)
##
## 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: For every one meter increase in depth, temperature decreseases 1.9 degrees Celsius. The model is statistically significant at the 0.01 level with a p-value less than 2.2e-16. 73.9% if the variability in temperature is explained by changes in depth. These findings are based on 9726 degrees of freedom.

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



NTLAIC <- lm(data = NTL_LTER_subset, temperature_C ~ depth +
            year4 + daynum)

#Choose a model by AIC in a Stepwise Algorithm
step(NTLAIC)
```

```
## Start:  AIC=26065.53
## temperature_C ~ depth + year4 + daynum
##
##          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 ~ depth + year4 + daynum, data = NTL_LTER_subset)
##
## Coefficients:
## (Intercept)        depth        year4       daynum
##    -8.57556     -1.94644      0.01134      0.03978
```

```
NTLmodel <- lm(data = NTL_LTER_subset, temperature_C ~ depth +
    year4 + daynum)
summary(NTLmodel)
```

```
##
## Call:
## lm(formula = temperature_C ~ depth + year4 + daynum, data = NTL_LTER_subset)
##
## 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
## depth       -1.946437   0.011683 -166.611  < 2e-16 ***
## year4        0.011345   0.004299    2.639  0.00833 **
## daynum       0.039780   0.004317    9.215  < 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
```

```
DepthFullRegression <- lm(data=NTL_LTER_subset, temperature_C ~ depth, daynum, year4)
summary(DepthFullRegression)
```

```
##
## Call:
## lm(formula = temperature_C ~ depth, data = NTL_LTER_subset, subset = daynum,
##     weights = year4)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -407.52 -131.57   45.32  145.22  369.45
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 22.83025    0.06793   336.1   <2e-16 ***
## depth       -1.69529    0.01082  -156.7   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 195.8 on 9726 degrees of freedom
## Multiple R-squared:  0.7164, Adjusted R-squared:  0.7163
## F-statistic: 2.456e+04 on 1 and 9726 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 final set of explanatory variables are depth, year4, and daynum. The model explains 71.6% of the observed variance which actually makes it a slightly worse model than 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).

```
unique(NTL_LTER_subset$lakename)
```

```
## [1] "Paul Lake"        "Peter Lake"       "Tuesday Lake"
## [4] "East Long Lake"   "West Long Lake"   "Central Long Lake"
## [7] "Hummingbird Lake" "Crampton Lake"    "Ward Lake"
```

```
LakesTempLinear <- lm(data=NTL_LTER_subset, temperature_C ~ lakename)

summary(LakesTempLinear)
```

```
##
## Call:
## lm(formula = temperature_C ~ lakename, data = NTL_LTER_subset)
##
## 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
```

```
LakesTempANOVA <- aov(data=NTL_LTER_subset, temperature_C ~ lakename)
summary(LakesTempANOVA)
```

```
##               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
```

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 at the 0.01 level with p-value less than 2e-16. The ANOVA alone does not indicate which lakes have a statistically significant difference in mean temperature.

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.

LakeTempScatter <- ggplot(NTL_LTER_subset, aes(x=depth, y=temperature_C, color=lakename)) +
  geom_point(alpha = 0.5)+
  ylim(0, 35)+
  ylab("Temperature in Celsius") +
  xlab("Depth (m)") +
  labs(color = "Lake Name")+
  geom_smooth(method = 'lm', se = FALSE, color = "blue")


print(LakeTempScatter)
```

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

Warning: Removed 24 rows containing missing values (geom_smooth).
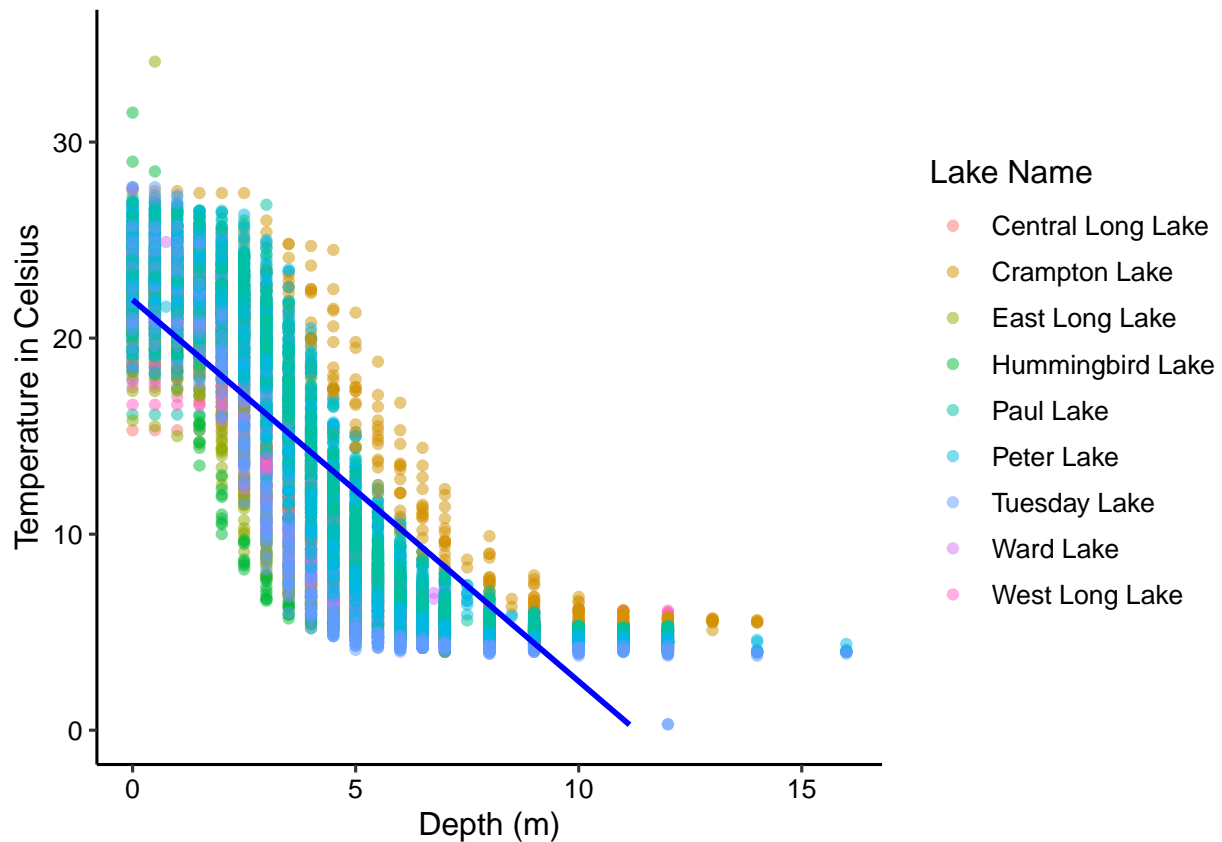
15. Use the Tukey's HSD test to determine which lakes have different means.

```
#15
TukeyHSD(LakesTempANOVA)
```

```
##     Tukey multiple comparisons of means
##       95% family-wise confidence level
##
## Fit: aov(formula = temperature_C ~ lakename, data = NTL_LTER_subset)
##
## $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
```

```r
LakesMeanDifferences <- HSD.test(LakesTempANOVA, "lakename", group = TRUE)

LakesMeanDifferences
```

```
## $statistics
##    MSerror   Df     Mean       CV
##    54.1016 9719 12.72087 57.82135
##
## $parameters
##     test   name.t ntr StudentizedRange alpha
```

```
##    Tukey lakename   9        4.387504  0.05
##
## $means
##                    temperature_C      std   r Min  Max    Q25   Q50    Q75
## Central Long Lake      17.66641 4.196292  128 8.9 26.8 14.400 18.40 21.000
## Crampton Lake          15.35189 7.244773  318 5.0 27.5  7.525 16.90 22.300
## East Long Lake         10.26767 6.766804  968 4.2 34.1  4.975  6.50 15.925
## Hummingbird Lake       10.77328 7.017845  116 4.0 31.5  5.200  7.00 15.625
## Paul Lake              13.81426 7.296928 2660 4.7 27.7  6.500 12.40 21.400
## Peter Lake             13.31626 7.669758 2872 4.0 27.0  5.600 11.40 21.500
## Tuesday Lake           11.06923 7.698687 1524 0.3 27.7  4.400  6.80 19.400
## Ward Lake              14.45862 7.409079  116 5.7 27.6  7.200 12.55 23.200
## West Long Lake         11.57865 6.980789 1026 4.0 25.7  5.400  8.00 18.800
##
## $comparison
## NULL
##
## $groups
##                    temperature_C groups
## Central Long Lake       17.66641      a
## Crampton Lake           15.35189     ab
## Ward Lake               14.45862     bc
## Paul Lake               13.81426      c
## Peter Lake              13.31626      c
## West Long Lake          11.57865      d
## Tuesday Lake            11.06923     de
## Hummingbird Lake        10.77328     de
## East Long Lake          10.26767      e
##
## attr(,"class")
## [1] "group"
```

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 and Ward Lakes have the same mean temperature to Peter Lake, statistically speaking. No lake has a statistically distinct temperature from all 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:

If we were just looking at Peter and Paul Lakes, we could use a t-test to explore whether they have distinct mean temperatures as an alternative method.

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