Assignment 2: Physical Properties of Lakes

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OVERVIEW

This exercise accompanies the lessons in Hydrologic Data Analysis on the physical properties of lakes.

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., "Salk_A02_LakePhysical.Rmd") prior to submission.

The completed exercise is due on 11 September 2019 at 9:00 am.

Setup

1. Verify your working directory is set to the R project file,
2. Load the tidyverse, lubridate, and cowplot packages
3. Import the NTL-LTER physical lake dataset and set the date column to the date format
4. Set your ggplot theme (can be theme_classic or something else)

```r
# Check Working Directory
getwd()
```

```
## [1] "/Users/jakegreif/Duke/Fall_2019/Hydrologic_Data_Analysis"
```

```r
# Load Packages
library(tidyverse)
library(lubridate)
library(cowplot)

# Import Data
NTLdata <- read.csv("./Data/Raw/NTL-LTER_Lake_ChemistryPhysics_Raw.csv")

# Set ggplot Theme
mytheme <- theme_classic()

theme_set(mytheme)
```

Creating and analyzing lake temperature profiles

Single lake, multiple dates

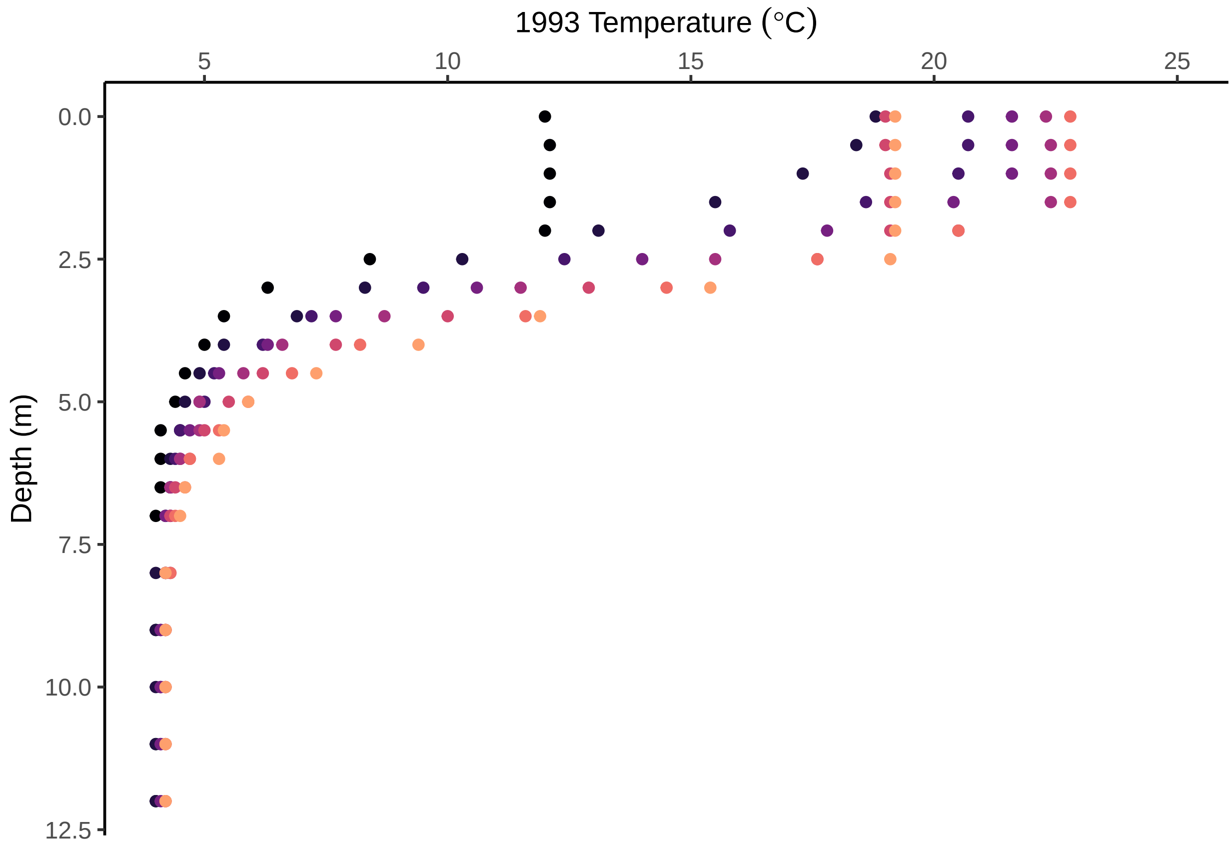
5. Choose either Peter or Tuesday Lake. Create a new data frame that wrangles the full data frame so that it only includes that lake during two different years (one year from the early part of the dataset and one year from the late part of the dataset).

```r
# Change sampledate to Date
NTLdata$sampledate <- as.Date(NTLdata$sampledate, "%m/%d/%y")

# Make Tuesday Lake data frame
Tuesdaydata <- filter(NTLdata, lakename == "Tuesday Lake")

# Trim Tuesday data frame to include only 1993 and 2016
Tues.data.skinny <- filter(Tuesdaydata, year4 == 1993 | year4 == 2016)

# Make 2 separate data frames for each year
Tues.1993 <- filter(Tues.data.skinny, year4 == 1993)
Tues.2016 <- filter(Tues.data.skinny, year4 == 2016)
```

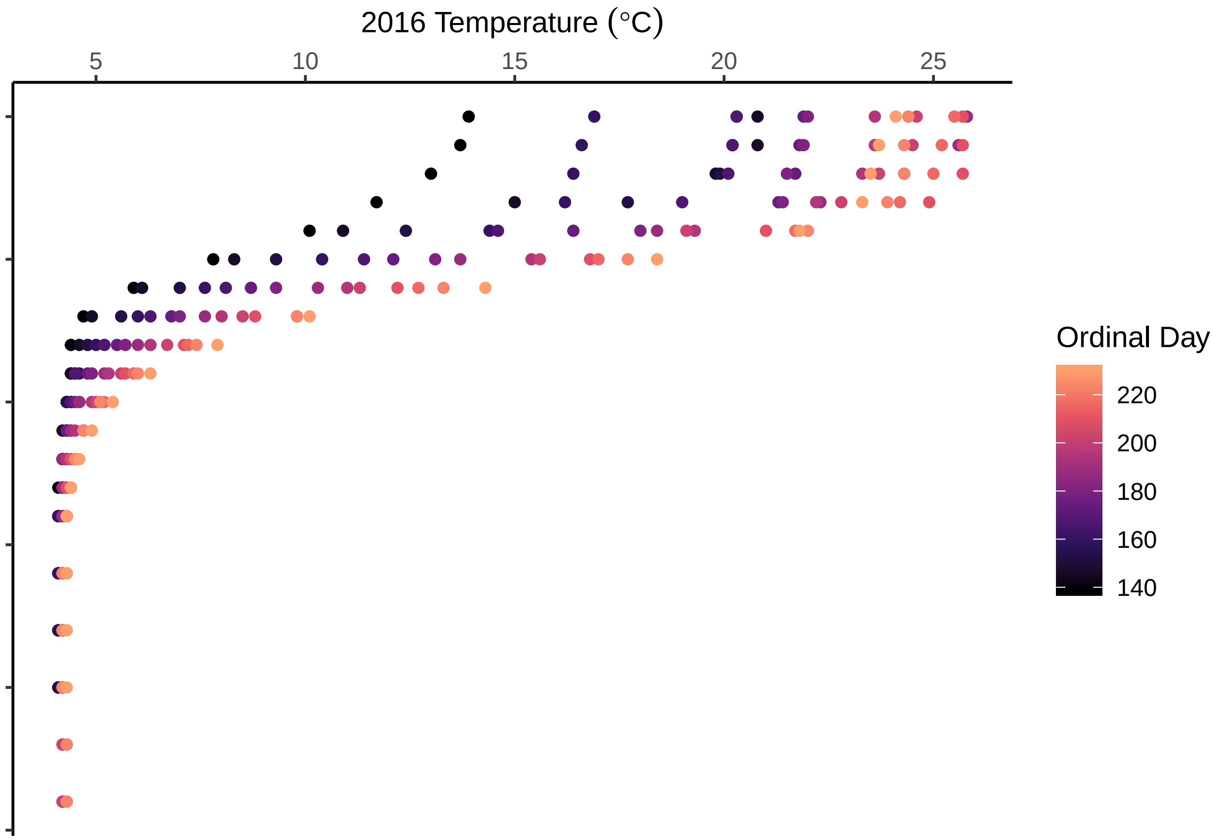
6. Create three graphs: (1) temperature profiles for the early year, (2) temperature profiles for the late year, and (3) a `plot_grid` of the two graphs together. Choose `geom_point` and color your points by date.

Remember to edit your graphs so they follow good data visualization practices.

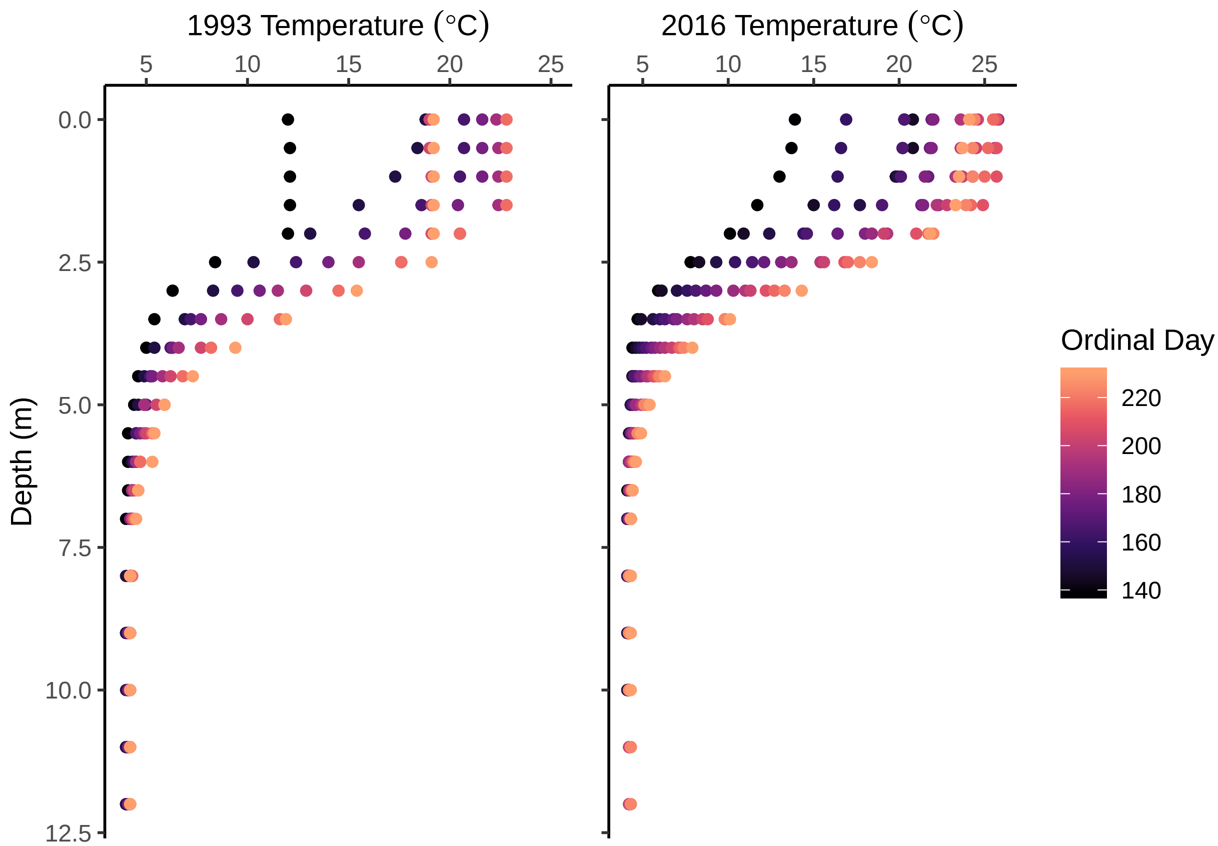
```r
Tempprofiles1993 <-
  ggplot(Tues.1993, aes(x = temperature_C,y = depth, color = daynum)) +
  geom_point() +
  scale_y_reverse() +
  scale_x_continuous(position = "top", limits = c(4,25)) +
  scale_color_viridis_c(end = 0.8, option = "magma") +
  labs(x = expression("1993 Temperature "(degree*C)), y = "Depth (m)") +
  theme(legend.position = "none")
print(Tempprofiles1993)
```




```
Tempprofiles2016 <-
  ggplot(Tues.2016, aes(x = temperature_C, y = depth, color = daynum)) +
  geom_point() +
  scale_y_reverse() +
  scale_x_continuous(position = "top") +
  scale_color_viridis_c(end = 0.8, option = "magma") +
  labs(x = expression("2016 Temperature "(degree*C)), y = "Depth (m)",
       color = "Ordinal Day") +
  theme(axis.text.y = element_blank(), axis.title.y = element_blank())
print(Tempprofiles2016)
```




```
Temp.1993.2016 <-
  plot_grid(Tempprofiles1993, Tempprofiles2016,
            ncol = 2, rel_widths = c(0.9, 1))
print(Temp.1993.2016)
```



7. Interpret the stratification patterns in your graphs in light of seasonal trends. In addition, do you see differences between the two years?

   Temperatures increase through the year, but the magnitude of the increase decreases with depth. Temperature essentially doesn't change below 7.5 m, which is due to thermal stratification and a lack of mixing in the summer. In 1993 the epilimnion was cooler throughout the summer than in 2016, but the metalimnion warmed slightly in 1993 compared to 2016.

Multiple lakes, single date

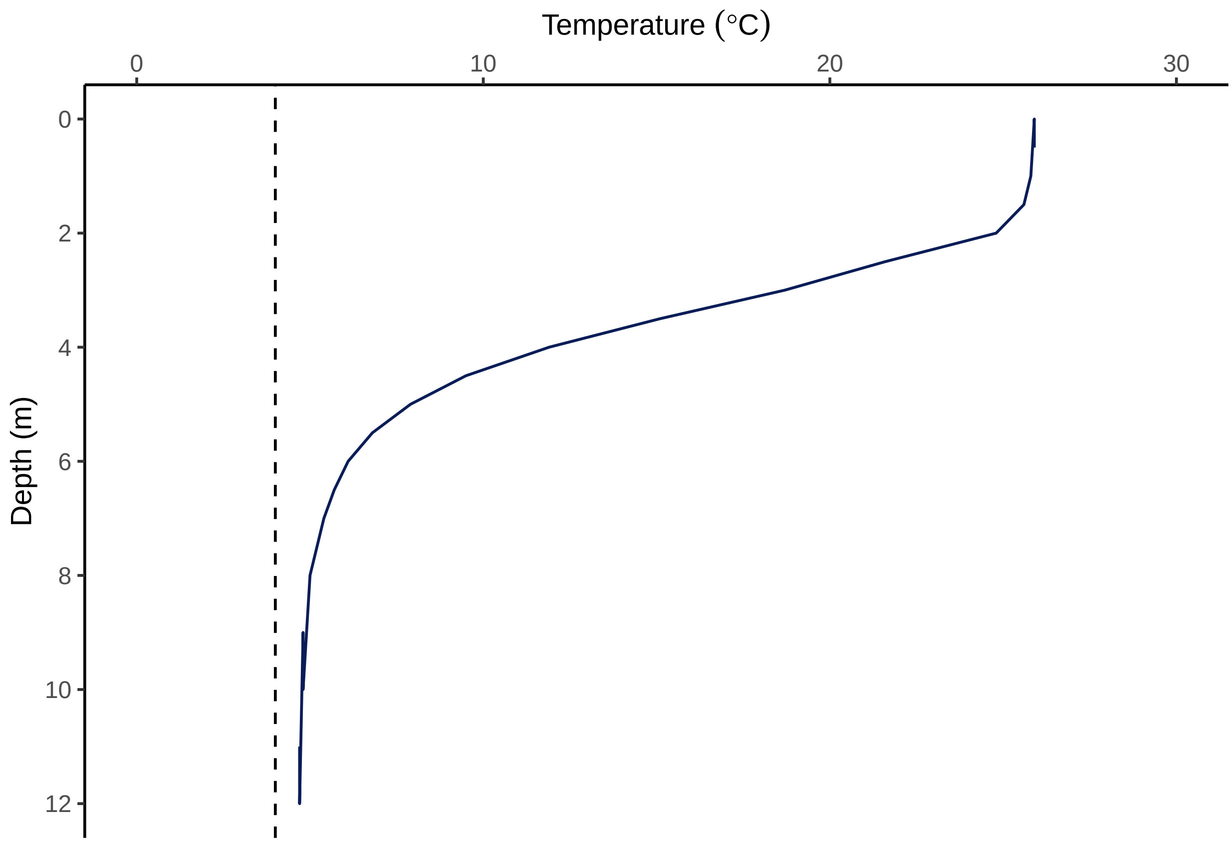
8. On July 25, 26, and 27 in 2016, all three lakes (Peter, Paul, and Tuesday) were sampled. Wrangle your data frame to include just these three dates.

```
July.2016 <- filter(NTLdata, lakename == "Peter Lake" |
                      lakename == "Paul Lake" |
                      lakename == "Tuesday Lake")
July.2016 <- filter(July.2016, sampledate == "2016-07-25" |
                      sampledate == "2016-07-26" |
                      sampledate == "2016-07-27")
```

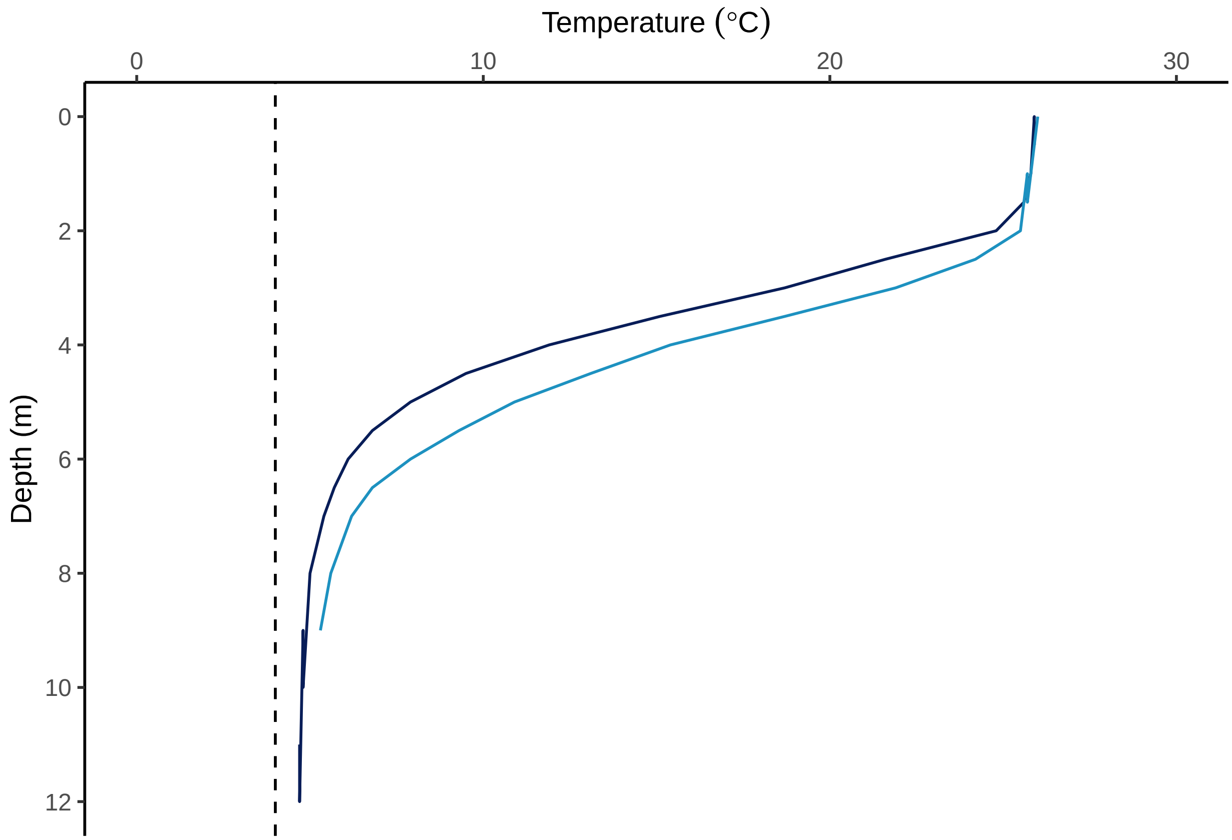
9. Plot a profile line graph of temperature by depth, one line per lake. Each lake can be designated by a separate color.

```
# Separate data frame by lake
Peter.July.2016 <- filter(July.2016, lakename == "Peter Lake")
Paul.July.2016 <- filter(July.2016, lakename == "Paul Lake")
Tues.July.2016 <- filter(July.2016, lakename == "Tuesday Lake")
```

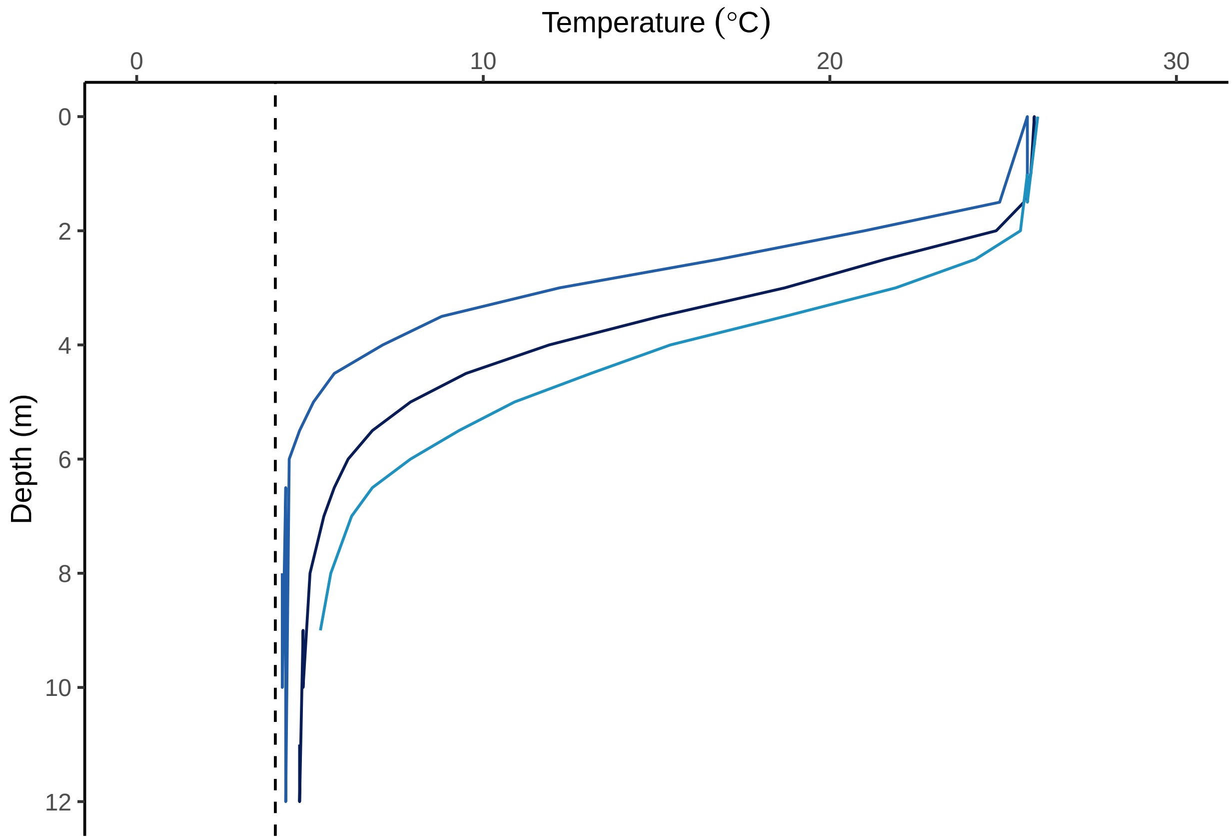
```r
# Plot temp profile of each lake
PeterTempProfileJuly2016 <-
  ggplot(Peter.July.2016, aes(x = temperature_C, y = depth)) +
  geom_line(color = "#081d58") +
  geom_vline(xintercept = 4, lty = 2) +
  scale_y_reverse(breaks = c(0, 2, 4, 6, 8, 10, 12)) +
  scale_x_continuous(position = "top", limits = c(0, 30)) +
  labs(x = expression("Temperature "(degree*C)), y = "Depth (m)")
print(PeterTempProfileJuly2016)
```




```r
PaulTempProfileJuly2016 <-
  PeterTempProfileJuly2016 +
  geom_line(data = Paul.July.2016, aes(x = temperature_C, y = depth),
            color = "#1d91c0")
print(PaulTempProfileJuly2016)
```




```r
TuesTempProfileJuly2016 <-
  PaulTempProfileJuly2016 +
  geom_line(data = Tues.July.2016, aes(x = temperature_C, y = depth),
            color = "#225ea8")
print(TuesTempProfileJuly2016)
```



10. What is the depth range of the epilimnion in each lake? The thermocline? The hypolimnion?

    The range of the epilimnion is from the surface to 3 meters. The range of the thermocline is from 2 meters to approximately 9 meters. And the range of the hypolmnion is from about 6 meters to the lake bed.

Trends in surface temperatures over time.

11. Run the same analyses we ran in class to determine if surface lake temperatures for a given month have increased over time ("Long-term change in temperature" section of day 4 lesson in its entirety), this time for either Peter or Tuesday Lake.

```
# 1. Add Month Column
Tuesdaydata$Month <- substring(Tuesdaydata$sampledate, 7,7)

# 2. Filter data frame
Tues.0 <- filter(Tuesdaydata, depth == 0)
Tues.summer <- filter(Tues.0, Month == c(5,6,7,8))
Tues.summer$Month[Tues.summer$Month == 5] <- "May"
Tues.summer$Month[Tues.summer$Month == 6] <- "June"
Tues.summer$Month[Tues.summer$Month == 7] <- "July"
Tues.summer$Month[Tues.summer$Month == 8] <- "August"

# 3. Create 4 Separate DF
Tues5 <- filter(Tues.summer, Month == "May")
Tues6 <- filter(Tues.summer, Month == "June")
```

```r
Tues7 <- filter(Tues.summer, Month == "July")
Tues8 <- filter(Tues.summer, Month == "August")

# 4. Run Linear Regression
Tues5.lm <- lm(data = Tues5, temperature_C ~ year4)
summary(Tues5.lm)
```

```
##
## Call:
## lm(formula = temperature_C ~ year4, data = Tues5)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -4.2491 -2.1410  0.1716  2.1112  5.3004
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  36.003218 171.065481   0.210    0.837
## year4        -0.009912   0.085786  -0.116    0.910
##
## Residual standard error: 3.039 on 11 degrees of freedom
## Multiple R-squared:  0.001212,   Adjusted R-squared:  -0.08959
## F-statistic: 0.01335 on 1 and 11 DF,  p-value: 0.9101
```

```r
Tues6.lm <- lm(data = Tues6, temperature_C ~ year4)
summary(Tues6.lm)
```

```
##
## Call:
## lm(formula = temperature_C ~ year4, data = Tues6)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -5.4907 -1.9893  0.0872  1.4401  4.4524
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 101.60736  111.36885   0.912    0.372
## year4        -0.04051    0.05577  -0.726    0.476
##
## Residual standard error: 2.722 on 20 degrees of freedom
## Multiple R-squared:  0.02571,    Adjusted R-squared:  -0.02301
## F-statistic: 0.5277 on 1 and 20 DF,  p-value: 0.476
```

```r
Tues7.lm <- lm(data = Tues7, temperature_C ~ year4)
summary(Tues7.lm)
```

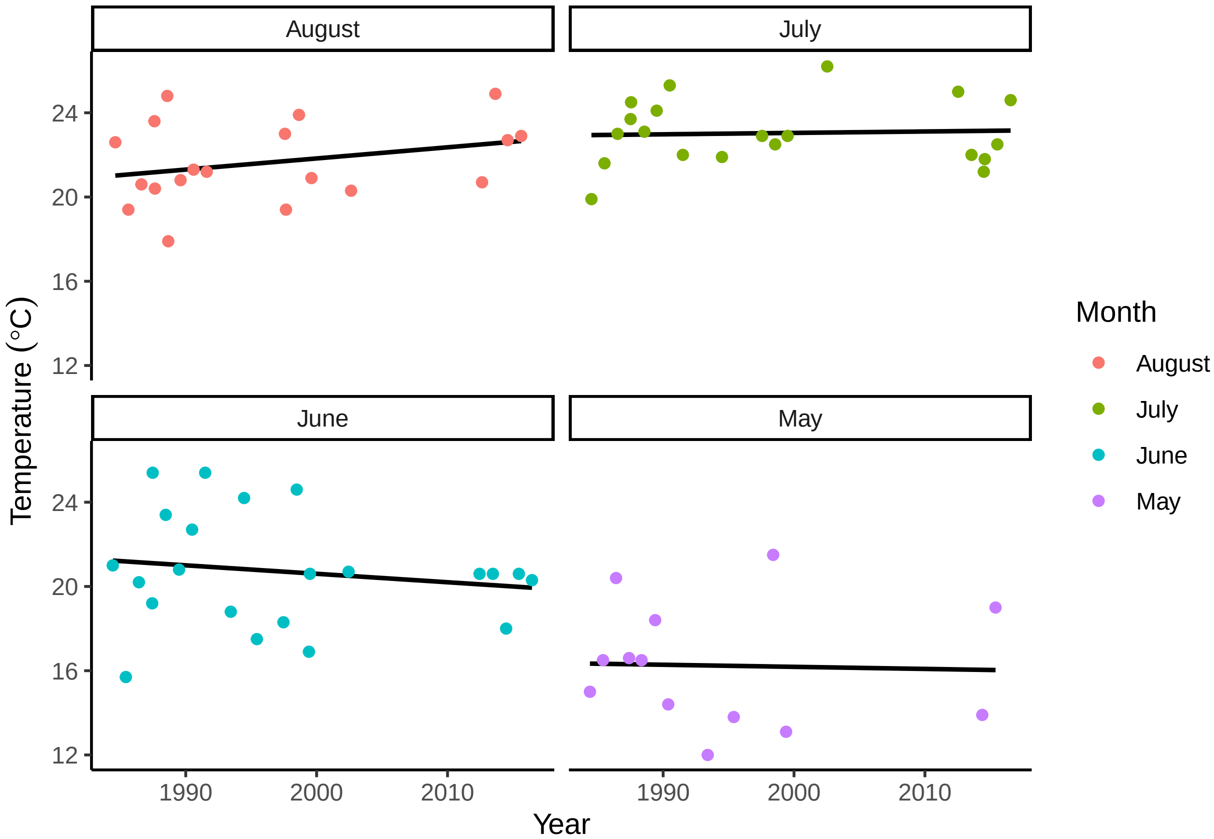
```
##
## Call:
## lm(formula = temperature_C ~ year4, data = Tues7)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -3.0410 -1.1147 -0.1347  1.2054  3.1386
##
```

```
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)  9.664936  62.268171   0.155    0.878
## year4        0.006692   0.031164   0.215    0.832
##
## Residual standard error: 1.597 on 18 degrees of freedom
## Multiple R-squared:  0.002555,   Adjusted R-squared:  -0.05286
## F-statistic: 0.04611 on 1 and 18 DF,  p-value: 0.8324
```

```
Tues8.lm <- lm(data = Tues8, temperature_C ~ year4)
summary(Tues8.lm)
```

```
##
## Call:
## lm(formula = temperature_C ~ year4, data = Tues8)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -3.3283 -1.2906 -0.1875  1.4390  3.5717
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -84.29885   83.01433  -1.015    0.324
## year4         0.05308    0.04159   1.276    0.219
##
## Residual standard error: 1.881 on 17 degrees of freedom
## Multiple R-squared:  0.08744,    Adjusted R-squared:  0.03376
## F-statistic: 1.629 on 1 and 17 DF,  p-value: 0.219
```

```
# 5. Calculate how many degrees the lake has warmed (for sig. trends)

# There are no signifcant surface temperature trends in Tuesday Lake.

# 6. Plot surface temps by date and facet by month
TuesSurfTemps <-
  ggplot(Tues.summer, aes(x = sampledate, y = temperature_C,
            color = Month)) +
  labs(x = "Year", y = expression("Temperature "(degree*C))) +
  geom_smooth(se = FALSE, method = lm, color = "black", size = 0.8) +
  geom_point() +
  facet_wrap(vars(Month), nrow = 2)
print(TuesSurfTemps)
```



12. How do your results compare to those we found in class for Paul Lake? Do similar trends exist for both lakes?

    There are no significant trends in Tuesday Lake, compared to Paul Lake which had significant increasing trends in two months.