EDF 5401 Midterm, Part 1: Hurricanes.

2013-10-15

These data come from the Data and Story Library

Most weather models note at relationship between the barimetric pressure and the peak wind speeds. A secondary question is, as the average temperature rises, is that relationship changing.

```
library(tidyverse)
```

```
-- Attaching core tidyverse packages ------------------------ tidyverse 2.0.0 --
v dplyr     1.1.3     v readr     2.1.4
v forcats   1.0.0     v stringr   1.5.0
v ggplot2   3.4.3     v tibble    3.2.1
v lubridate 1.9.2     v tidyr     1.3.0
v purrr     1.0.2
-- Conflicts ------------------------------------------ tidyverse_conflicts() --
x dplyr::filter() masks stats::filter()
x dplyr::lag()    masks stats::lag()
i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to beco
```

```
library(DescTools)
```

Part 1 Hurricanes

Exploratory Analysis

Load the data

Load the data. Force category to be an ordered category.

```r
hurric <- read_delim("hurricanes-2015.txt")
```

```
Rows: 226 Columns: 5
-- Column specification --------------------------------------------------------
Delimiter: "\t"
chr (1): Name
dbl (4): Year, Max.Wind.Speed(kts), Central.Pressure(mb), Category

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
hurric$Category <- ordered(hurric$Category)
summary(hurric)
```

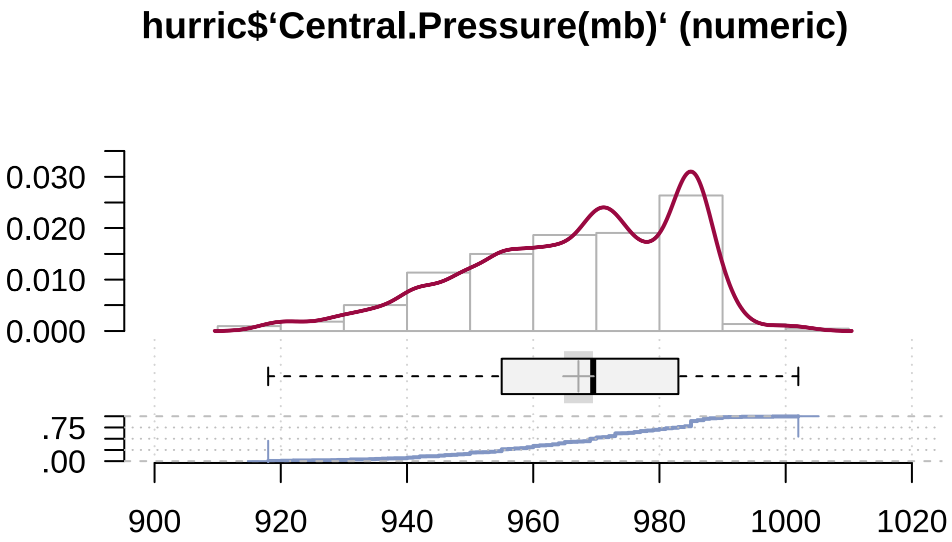
```
     Name                Year      Max.Wind.Speed(kts) Central.Pressure(mb)
 Length:226         Min.   :1851   Min.   : 65.00      Min.   : 918.0      
 Class :character   1st Qu.:1882   1st Qu.: 70.00      1st Qu.: 955.0      
 Mode  :character   Median :1910   Median : 85.00      Median : 969.5      
                    Mean   :1939   Mean   : 88.78      Mean   : 967.2      
                    3rd Qu.:2006   3rd Qu.:100.00      3rd Qu.: 983.0      
                    Max.   :2015   Max.   :150.00      Max.   :1002.0      
                                                       NA's   :6           
 Category
 1   :92  
 2   :55  
 3   :49  
 4   :17  
 5   : 3  
 NA's:10  
```

One-dimensional analyses

```r
Desc(hurric$`Central.Pressure(mb)`)
```

```
------------------------------------------------------------------------------
hurric$`Central.Pressure(mb)` (numeric)
```

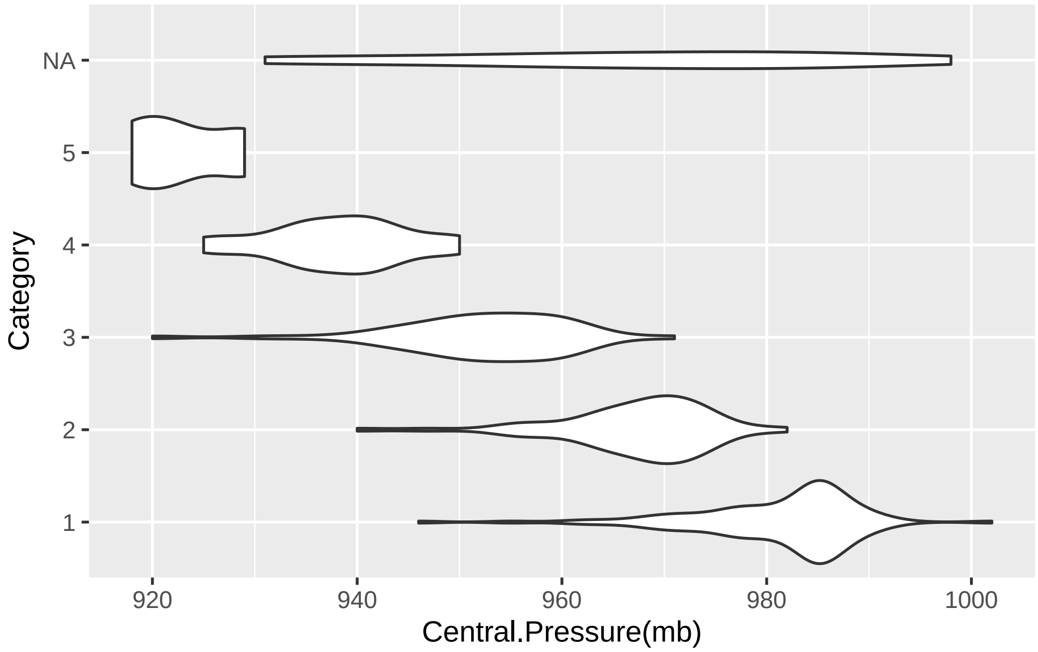
```
  length        n      NAs  unique       0s     mean  meanCI'
     226      220        6      66        0   967.16  964.90
            97.3%     2.7%             0.0%           969.43

     .05      .10      .25  median      .75      .90      .95
  935.95   942.00   955.00  969.50   983.00   986.00   988.00

   range       sd    vcoef     mad      IQR     skew     kurt
   84.00    17.04     0.02   20.76    28.00    -0.59    -0.30

lowest : 918.0, 920.0, 922.0, 925.0, 928.0
highest: 990.0 (4), 991.0, 993.0, 998.0, 1'002.0

heap(?): remarkable frequency (11.8%) for the mode(s) (= 985)

' 95%-CI (classic)
```



Look at differences in pressure by category.

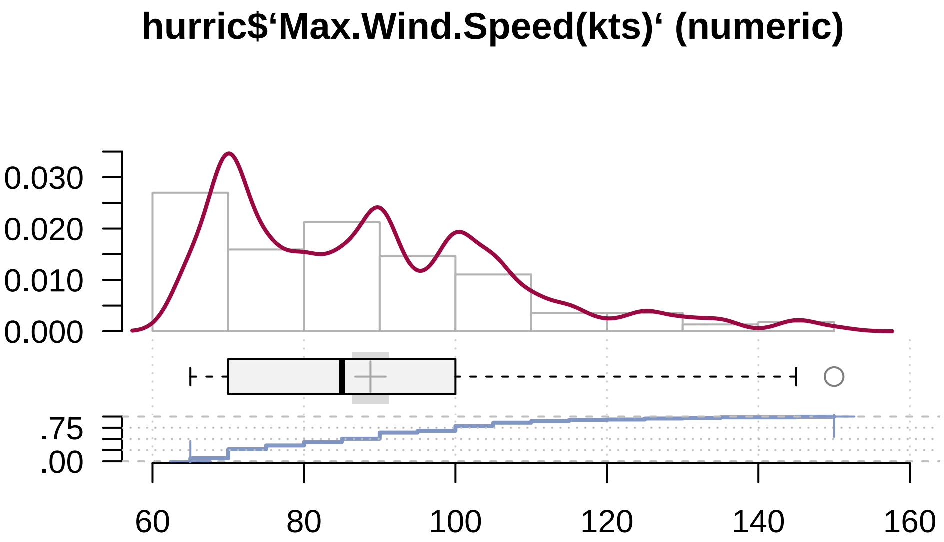
```
ggplot(hurric, aes(x=`Central.Pressure(mb)`,y=Category)) + geom_violin()
```

```
Warning: Removed 6 rows containing non-finite values (`stat_ydensity()`).
```



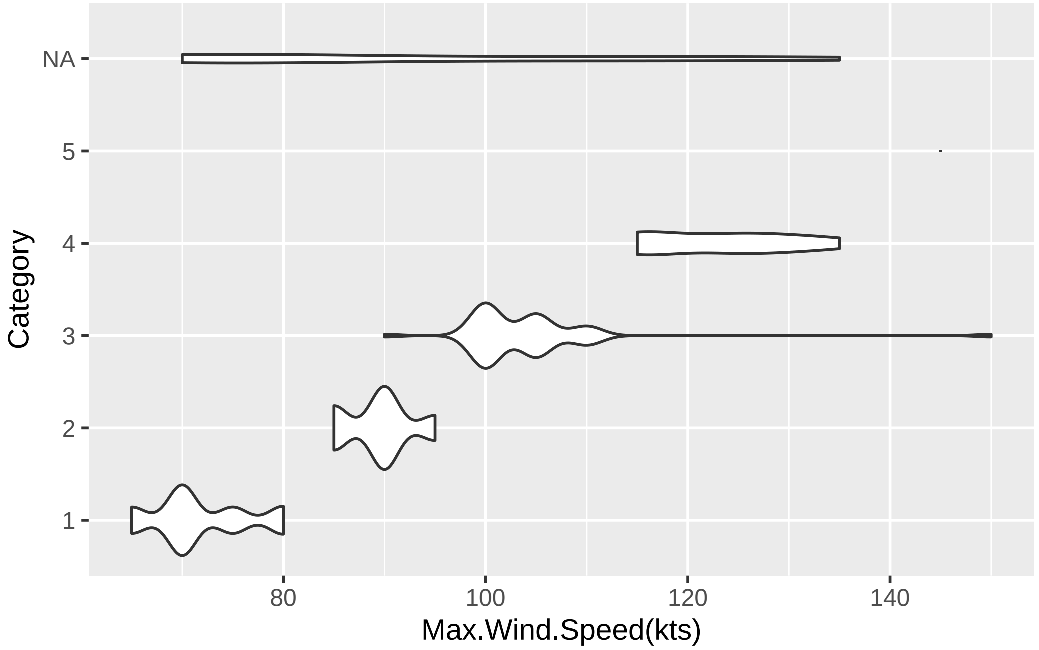
```
Desc(hurric$`Max.Wind.Speed(kts)`)
```

```
------------------------------------------------------------------------------
hurric$`Max.Wind.Speed(kts)` (numeric)

  length       n    NAs  unique      0s    mean  meanCI'
     226     226      0      17       0   88.78   86.33
          100.0%   0.0%            0.0%           91.24

     .05     .10    .25  median     .75     .90     .95
   65.00   70.00  70.00   85.00  100.00  112.50  125.00

   range      sd  vcoef     mad     IQR    skew    kurt
   85.00   18.73   0.21   22.24   30.00    0.86    0.39

lowest : 65.0 (16), 70.0 (45), 75.0 (19), 80.0 (17), 85.0 (17)
highest: 125.0 (5), 130.0 (3), 135.0 (3), 145.0 (3), 150.0

heap(?): remarkable frequency (19.9%) for the mode(s) (= 70)

' 95%-CI (classic)
```



Look at differences in maximum speed by category. (Note category is largely defined by wind speed.)

```
ggplot(hurric, aes(x=`Max.Wind.Speed(kts)`,y=Category)) + geom_violin()
```



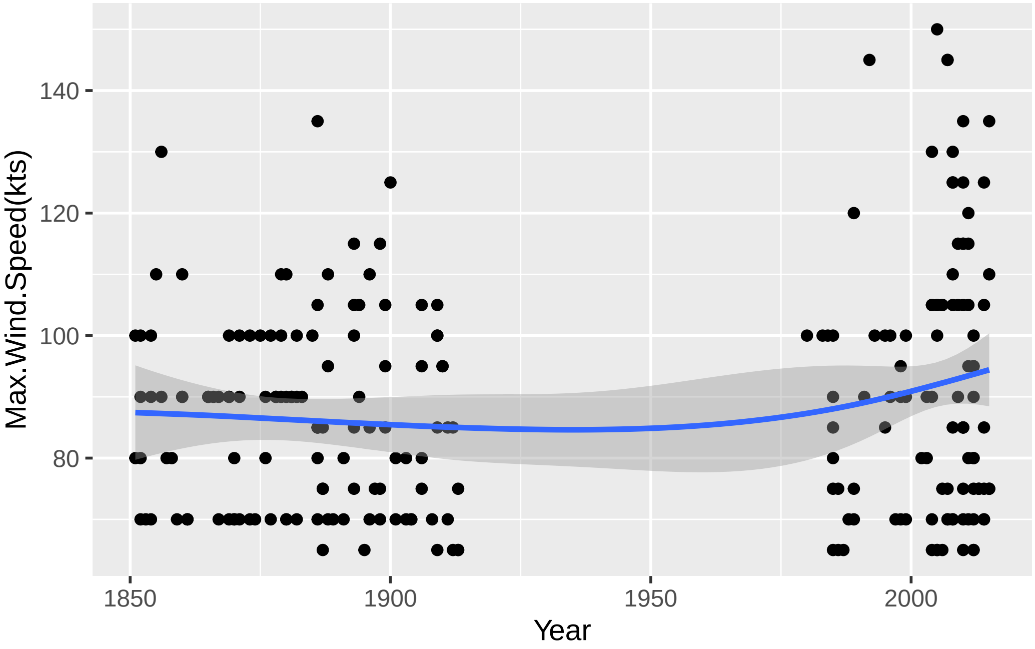
Relationships with time

```
round(cor(hurric[,2:4],use="complete.obs"),3)
```

```
                      Year Max.Wind.Speed(kts) Central.Pressure(mb)
Year                 1.000               0.131               -0.147
Max.Wind.Speed(kts)  0.131               1.000               -0.898
Central.Pressure(mb) -0.147             -0.898                1.000
```

```
ggplot(hurric,aes(x=Year,y=`Max.Wind.Speed(kts)`)) +
  geom_point() + geom_smooth()
```

```
`geom_smooth()` using method = 'loess' and formula = 'y ~ x'
```



Hmm. Note big gap in data between 1925 and 1975. Maybe before/after climate change? Note 1950 appears to be a cut point.

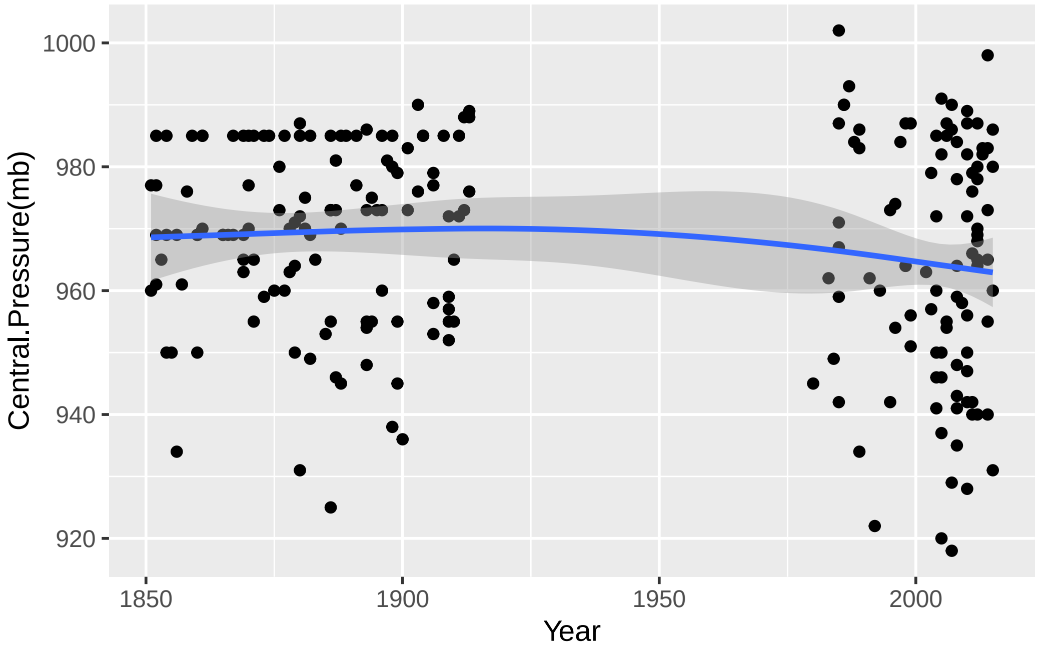
```
hurric <- mutate(hurric,recent=Year>1950)
```

```
ggplot(hurric,aes(x=Year,y=`Central.Pressure(mb)`)) +
  geom_point() + geom_smooth()
```

```
`geom_smooth()` using method = 'loess' and formula = 'y ~ x'
```

```
Warning: Removed 6 rows containing non-finite values (`stat_smooth()`).
```

```
Warning: Removed 6 rows containing missing values (`geom_point()`).
```



Scatterplots

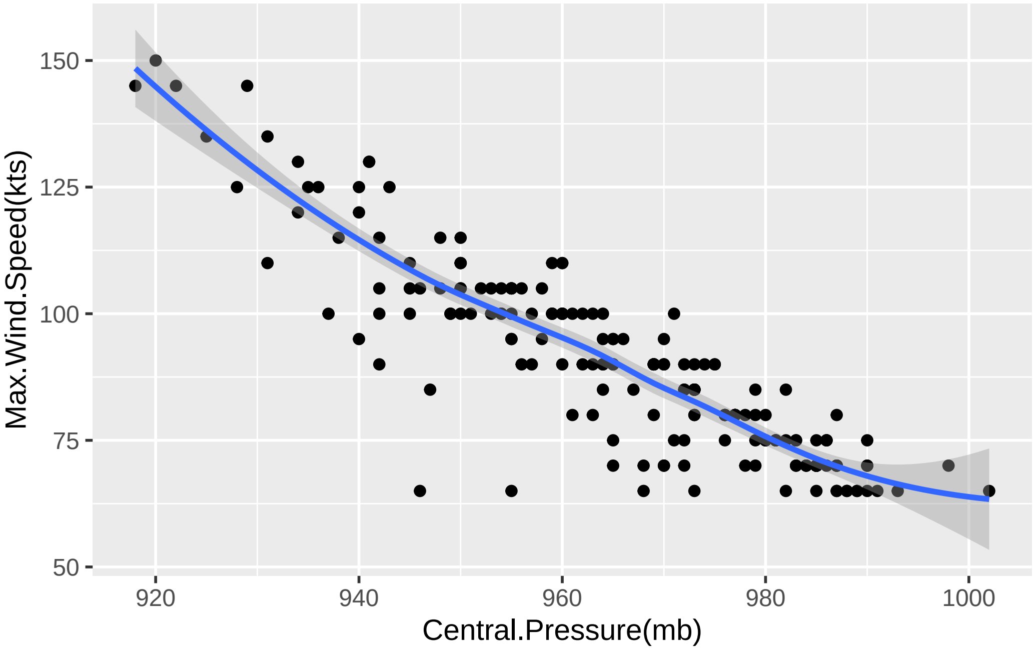
XY

```
ggplot(hurric,aes(x=`Central.Pressure(mb)`,y=`Max.Wind.Speed(kts)`)) +
  geom_point() + geom_smooth()
```

```
`geom_smooth()` using method = 'loess' and formula = 'y ~ x'
```

```
Warning: Removed 6 rows containing non-finite values (`stat_smooth()`).
```

```
Warning: Removed 6 rows containing missing values (`geom_point()`).
```



Jittered

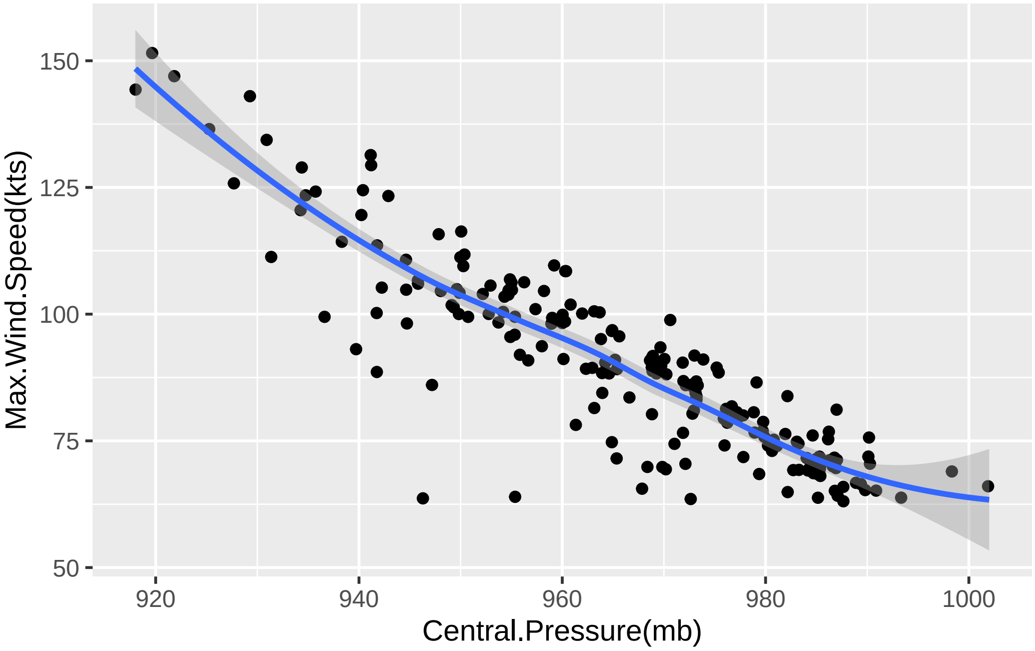
Hmm. Points lying on top of each other, try some jittering.

```
ggplot(hurric,aes(x=`Central.Pressure(mb)`,y=`Max.Wind.Speed(kts)`)) +
  geom_point(position="jitter") + geom_smooth()
```

```
`geom_smooth()` using method = 'loess' and formula = 'y ~ x'
```

```
Warning: Removed 6 rows containing non-finite values (`stat_smooth()`).
```

```
Warning: Removed 6 rows containing missing values (`geom_point()`).
```



XY by Recent

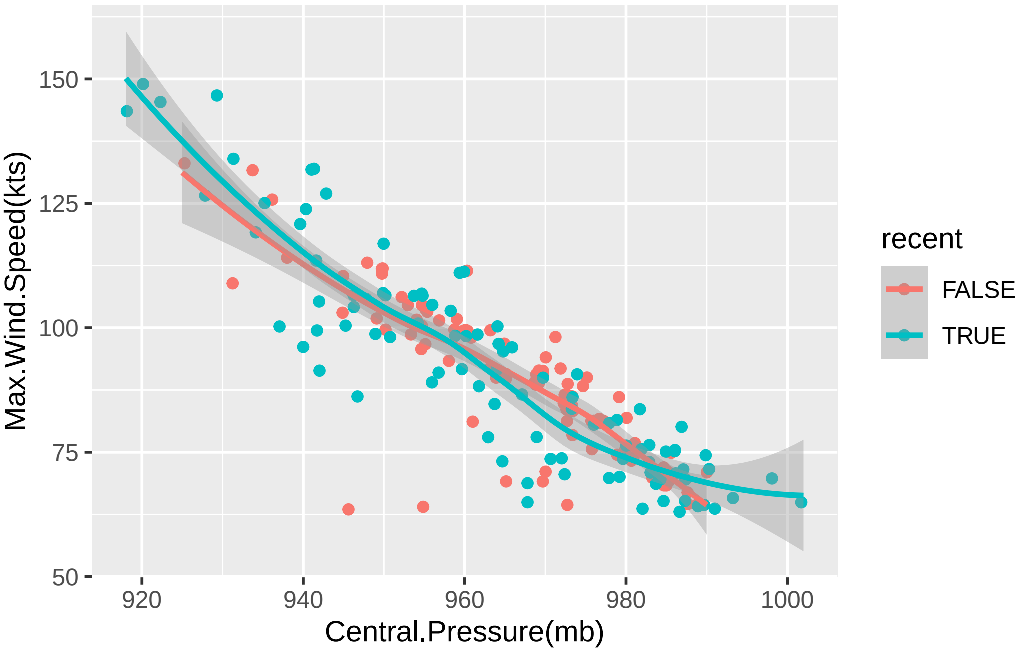
Color by recent to see if the current and recent groups are similar or not.

```
ggplot(hurric,aes(x=`Central.Pressure(mb)`,y=`Max.Wind.Speed(kts)`,color=recent)) +
  geom_point(position="jitter") + geom_smooth()
```

```
`geom_smooth()` using method = 'loess' and formula = 'y ~ x'
```

```
Warning: Removed 6 rows containing non-finite values (`stat_smooth()`).
```

```
Warning: Removed 6 rows containing missing values (`geom_point()`).
```



Outliers

There seem to be a couple of ouliers. Lets try to find them.

```
hout <- which(hurric$`Central.Pressure(mb)`<960 &
                hurric$`Max.Wind.Speed(kts)` < 75)
hurric[hout,]
```

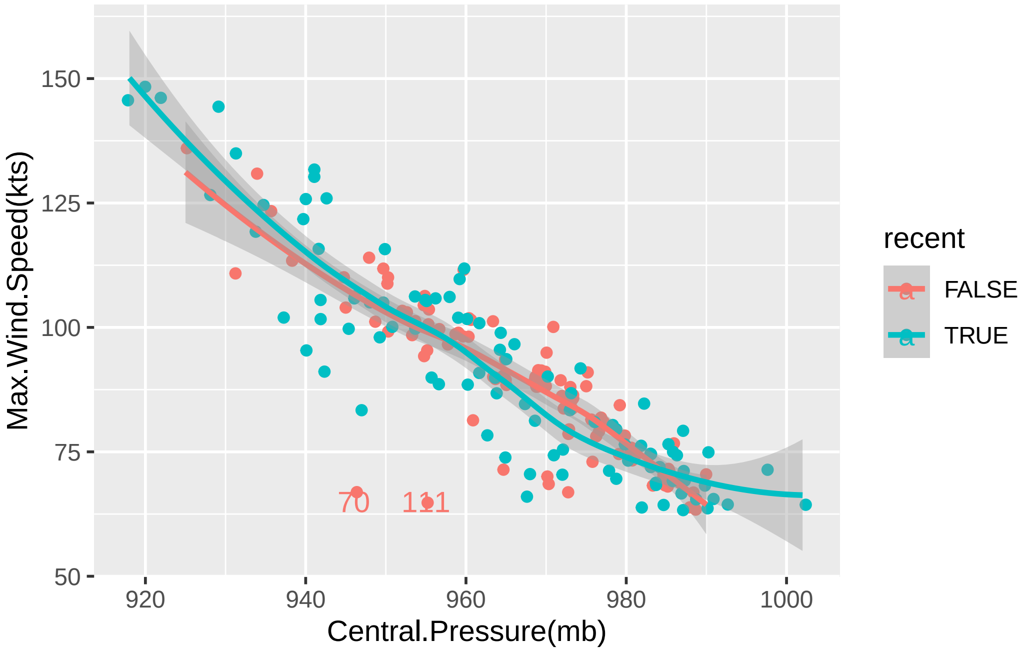
```
# A tibble: 2 x 6
  Name   Year `Max.Wind.Speed(kts)` `Central.Pressure(mb)` Category recent
  <chr> <dbl>                 <dbl>                  <dbl> <ord>    <lgl>
1 -----  1887                    65                    946 1        FALSE
2 -----  1909                    65                    955 1        FALSE
```

```
ggplot(hurric,aes(x=`Central.Pressure(mb)`,y=`Max.Wind.Speed(kts)`,
                  color=recent)) +
  geom_point(position="jitter") + geom_smooth() +
  geom_text(data=hurric[hout,],aes(label=hout))
```

```
`geom_smooth()` using method = 'loess' and formula = 'y ~ x'
```

```
Warning: Removed 6 rows containing non-finite values (`stat_smooth()`).
```

```
Warning: Removed 6 rows containing missing values (`geom_point()`).
```



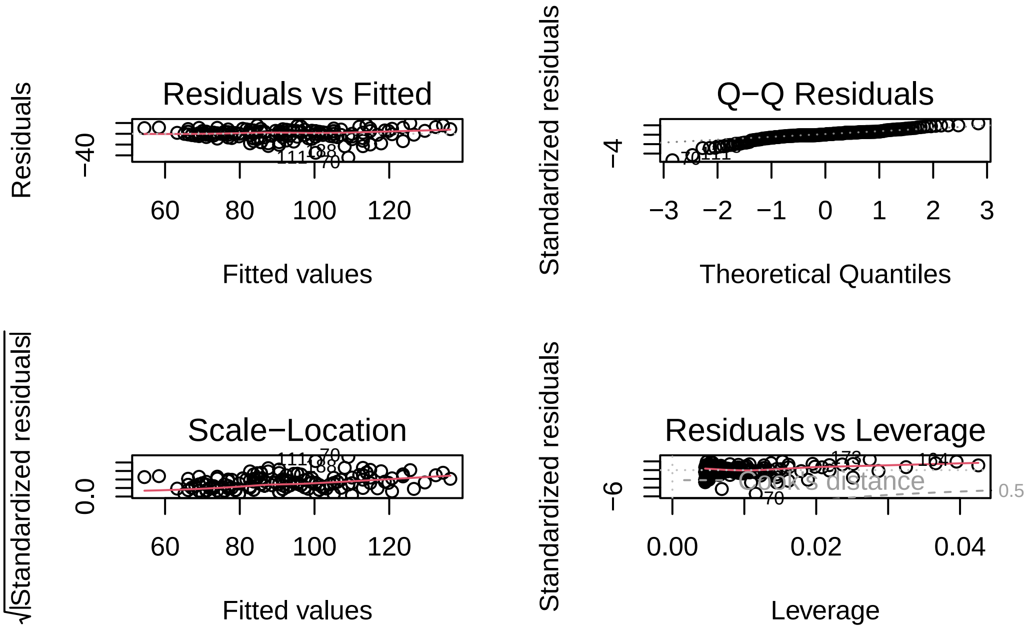
Build the Regression Model

```
lm_hurric <- lm(`Max.Wind.Speed(kts)` ~ `Central.Pressure(mb)`, data=hurric)
summary(lm_hurric)
```

```

Call:
lm(formula = `Max.Wind.Speed(kts)` ~ `Central.Pressure(mb)`,
    data = hurric)

Residuals:
    Min      1Q  Median      3Q     Max
-44.063  -2.145   0.182   4.459  19.365

Coefficients:
                         Estimate Std. Error t value Pr(>|t|)
```

```
(Intercept)             1031.24439   31.37284   32.87   <2e-16 ***
`Central.Pressure(mb)`    -0.97482    0.03243  -30.06   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 8.18 on 218 degrees of freedom
  (6 observations deleted due to missingness)
Multiple R-squared:  0.8056,    Adjusted R-squared:  0.8047
F-statistic: 903.4 on 1 and 218 DF,  p-value: < 2.2e-16
```

```
oldpar <- par(mfrow=c(2,2))
plot(lm_hurric)
```



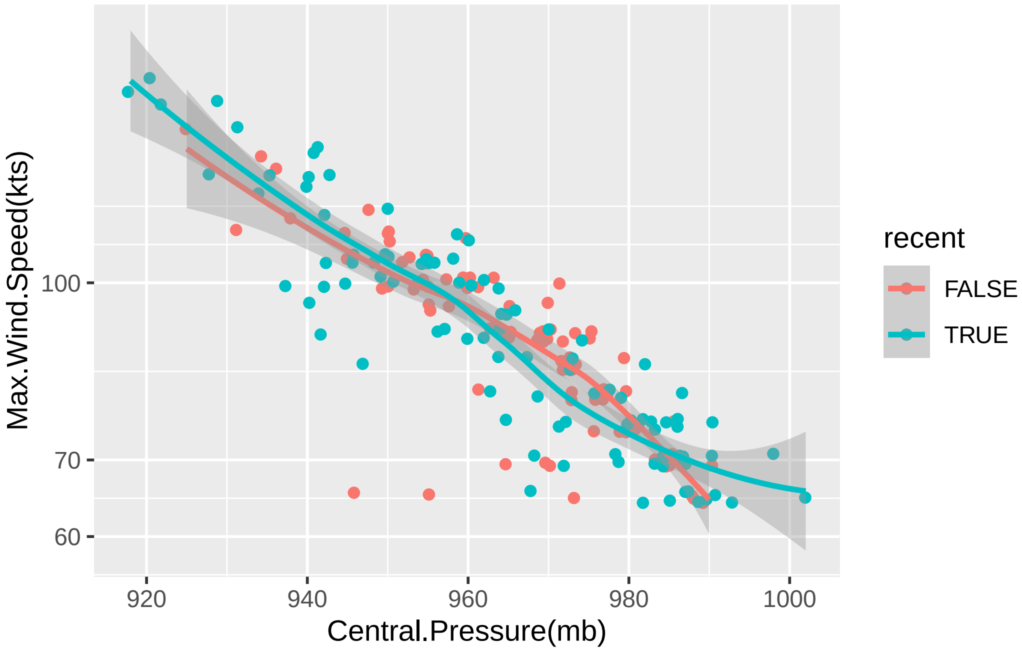
```
par(oldpar)
```

Try some Y transforms

Log

```
ggplot(hurric,aes(x=`Central.Pressure(mb)`,y=`Max.Wind.Speed(kts)`,color=recent)) +
  geom_point(position="jitter") + geom_smooth() + scale_y_log10()
```

```
`geom_smooth()` using method = 'loess' and formula = 'y ~ x'

Warning: Removed 6 rows containing non-finite values (`stat_smooth()`).

Warning: Removed 6 rows containing missing values (`geom_point()`).
```



Log model

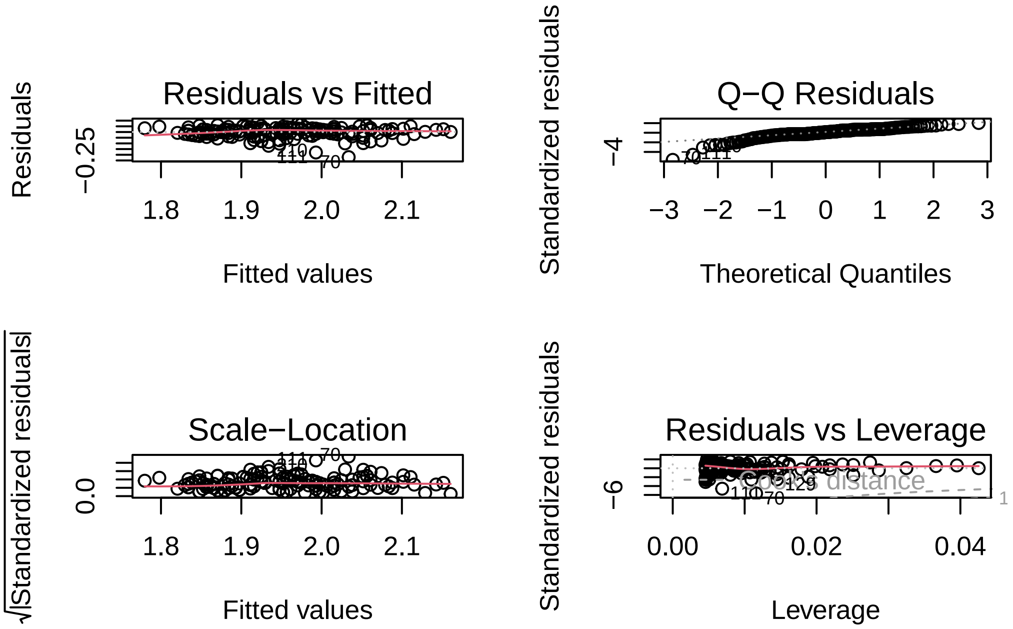
```
llm_hurric <- lm(log(`Max.Wind.Speed(kts)`,10) ~ `Central.Pressure(mb)`, data=hurric)
summary(llm_hurric)
```

```
Call:
lm(formula = log(`Max.Wind.Speed(kts)`, 10) ~ `Central.Pressure(mb)`,
    data = hurric)

Residuals:
      Min        1Q    Median        3Q       Max
-0.220809 -0.011784  0.004988  0.024811  0.079637

Coefficients:
```

```
                        Estimate Std. Error t value Pr(>|t|)    
(Intercept)            6.3232468  0.1506825   41.96   <2e-16 ***
`Central.Pressure(mb)` -0.0045344  0.0001558  -29.11   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.03929 on 218 degrees of freedom
  (6 observations deleted due to missingness)
Multiple R-squared:  0.7954,	Adjusted R-squared:  0.7944 
F-statistic: 847.3 on 1 and 218 DF,  p-value: < 2.2e-16
```

Log Diagnostics

```r
oldpar <- par(mfrow=c(2,2))
plot(llm_hurric)
```



```r
par(oldpar)
```

Flipping a coin, I'm doing the rest of the analyses on the linear scale.

Outliers

Calculate dfbetas for identified outliers

```
dfbetas(lm_hurric)[hout,]
```

```
    (Intercept) `Central.Pressure(mb)`
70   -0.4973275              0.4904759
111  -0.2239674              0.2186286
```

Run the regression without the outliers.

```
lm_hurric_no <-  lm(`Max.Wind.Speed(kts)` ~ `Central.Pressure(mb)`,
                    data=hurric, subset=-hout)
summary(lm_hurric_no)
```

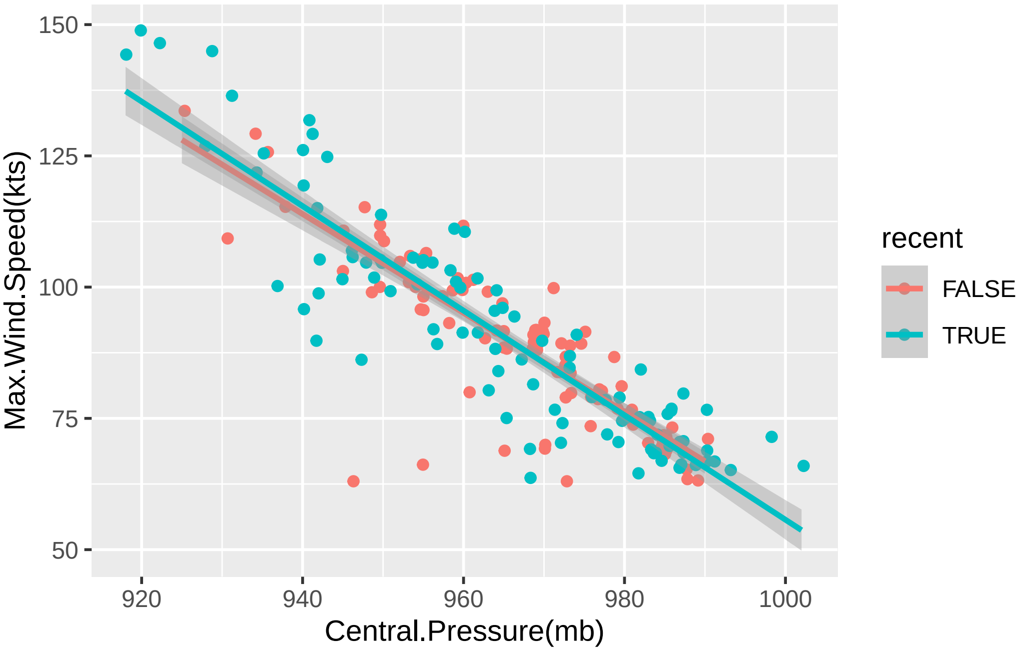
```

Call:
lm(formula = `Max.Wind.Speed(kts)` ~ `Central.Pressure(mb)`,
    data = hurric, subset = -hout)

Residuals:
     Min       1Q   Median       3Q      Max
-23.8948  -2.6321   0.4889   4.0445  18.1659

Coefficients:
                         Estimate Std. Error t value Pr(>|t|)
(Intercept)            1052.70051   27.92752   37.69   <2e-16 ***
`Central.Pressure(mb)`   -0.99663    0.02887  -34.52   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 7.246 on 216 degrees of freedom
  (6 observations deleted due to missingness)
Multiple R-squared:  0.8466,    Adjusted R-squared:  0.8459
F-statistic:  1192 on 1 and 216 DF,  p-value: < 2.2e-16
```

Run separately for old and recent data.

Redo the plot with `method="lm"` to visualize different lines.

```
ggplot(hurric,aes(x=`Central.Pressure(mb)`,y=`Max.Wind.Speed(kts)`,color=recent)) +
  geom_point(position="jitter") + geom_smooth(method="lm")
```

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

Warning: Removed 6 rows containing non-finite values (`stat_smooth()`).

Warning: Removed 6 rows containing missing values (`geom_point()`).
```



19th C, Early 20th

```
lm_hurric_19 <-  lm(`Max.Wind.Speed(kts)` ~ `Central.Pressure(mb)`,
                    data=hurric, subset=!recent)
summary(lm_hurric_19)
```

```
Call:
lm(formula = `Max.Wind.Speed(kts)` ~ `Central.Pressure(mb)`,
    data = hurric, subset = !recent)

Residuals:
    Min      1Q  Median      3Q     Max 
-43.276  -1.539   0.273   3.389  15.273 

Coefficients:
                        Estimate Std. Error t value Pr(>|t|)    
(Intercept)            999.38405   46.70347   21.40   <2e-16 ***
`Central.Pressure(mb)`  -0.94197    0.04817  -19.56   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 7.497 on 120 degrees of freedom
Multiple R-squared:  0.7612,    Adjusted R-squared:  0.7592 
F-statistic: 382.4 on 1 and 120 DF,  p-value: < 2.2e-16
```

```
## Save slope and SE for later processing.
hurric_slope_19 <- summary(lm_hurric_19)$coefficients[2,1:2]
```

Late 20th, Early 21st

```
lm_hurric_20 <-  lm(`Max.Wind.Speed(kts)` ~ `Central.Pressure(mb)`,
                    data=hurric, subset=recent)
summary(lm_hurric_20)
```

```

Call:
lm(formula = `Max.Wind.Speed(kts)` ~ `Central.Pressure(mb)`, 
    data = hurric, subset = recent)

Residuals:
     Min       1Q   Median       3Q      Max 
-23.4643  -4.4765   0.8828   5.1694  18.6154 

Coefficients:
                        Estimate Std. Error t value Pr(>|t|)    
(Intercept)            1051.2682    44.6541   23.54   <2e-16 ***
`Central.Pressure(mb)`   -0.9956     0.0463  -21.50   <2e-16 ***
```

```
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 9.014 on 96 degrees of freedom
  (6 observations deleted due to missingness)
Multiple R-squared:  0.8281,	Adjusted R-squared:  0.8263
F-statistic: 462.4 on 1 and 96 DF,  p-value: < 2.2e-16
```

```
## Save slope and SE for later processing.
hurric_slope_20 <- summary(lm_hurric_20)$coefficients[2,1:2]
```

Compare slopes in a table:

```
rbind(early=hurric_slope_19,
      late=hurric_slope_20)
```

```
        Estimate Std. Error
early -0.9419745 0.04816806
late  -0.9955690 0.04629930
```

Standard error for the difference is $\sqrt{s_1^2 + s_2^2}$

```
sqrt(hurric_slope_19[2]^2+hurric_slope_20[2]^2)
```

```
Std. Error
0.06681158
```