Time Series HW 2

Allison Theobold, Andrea Mack (Answers checked with Meryl Storb & Katie Fogg)

September 9, 2016

```
## Allison's code

rawbozemandata <- read.csv("https://dl.dropboxusercontent.com/u/77307195/rawbozemandata.csv",
                           header = T)

library(dplyr, quietly = T)
library(zoo, quietly = T)

rawd <- tbl_df(rawbozemandata) %>%
  mutate(DATE = as.yearmon(as.character(DATE), "%Y%m"))

rawd2 <- mutate(rawd, YEAR = as.numeric(format(DATE, "%Y"))) %>%
  mutate(MONTH = as.factor(format(DATE, "%m")))

rawd2 <- mutate(rawd2, YEARFRAC = YEAR + (as.numeric(MONTH) - 1)/12)
```

```
## Andrea's code
setwd("C:/Users/Andrea Mack/Desktop/mack_hub/course_work/Time Series/Homework/HW2")
rawbozemandata <- read.csv("rawbozemandata.csv", stringsAsFactors = FALSE)
rawd <- NULL
rawd <- data.frame(rawbozemandata)
rawd$year <- as.numeric(substring(rawd$DATE, 1,4))
rawd$month <- as.numeric(substring(rawd$DATE, 5,6))
rawd$month.dec <- rawd$month/12
rawd$date.new <- rawd$year + rawd$month.dec
rawd$month <- month.abb[((rawd$month))]
rawd$temp <- rawd$MMXT
```

1.

The model using the linear time trend for year and month is:

$$\widehat{temp_i} = -69.2902 + 0.0517 \text{ Year}_i + 3.7058 \text{ I(February)} + 11.198 \text{ I(March)} + 21.9902 \text{ I(April)} + 31.2412 \text{ I(May)} + 39.7299 \text{ I(June)} + 49.5908 \text{ I(July)} + 48.496 \text{ I(August)} + 37.6638 \text{ I(September)} + 25.8609 \text{ I(October)} + 10.3582 \text{ I(November)} + 1.7802 \text{ I(December)}$$

2.

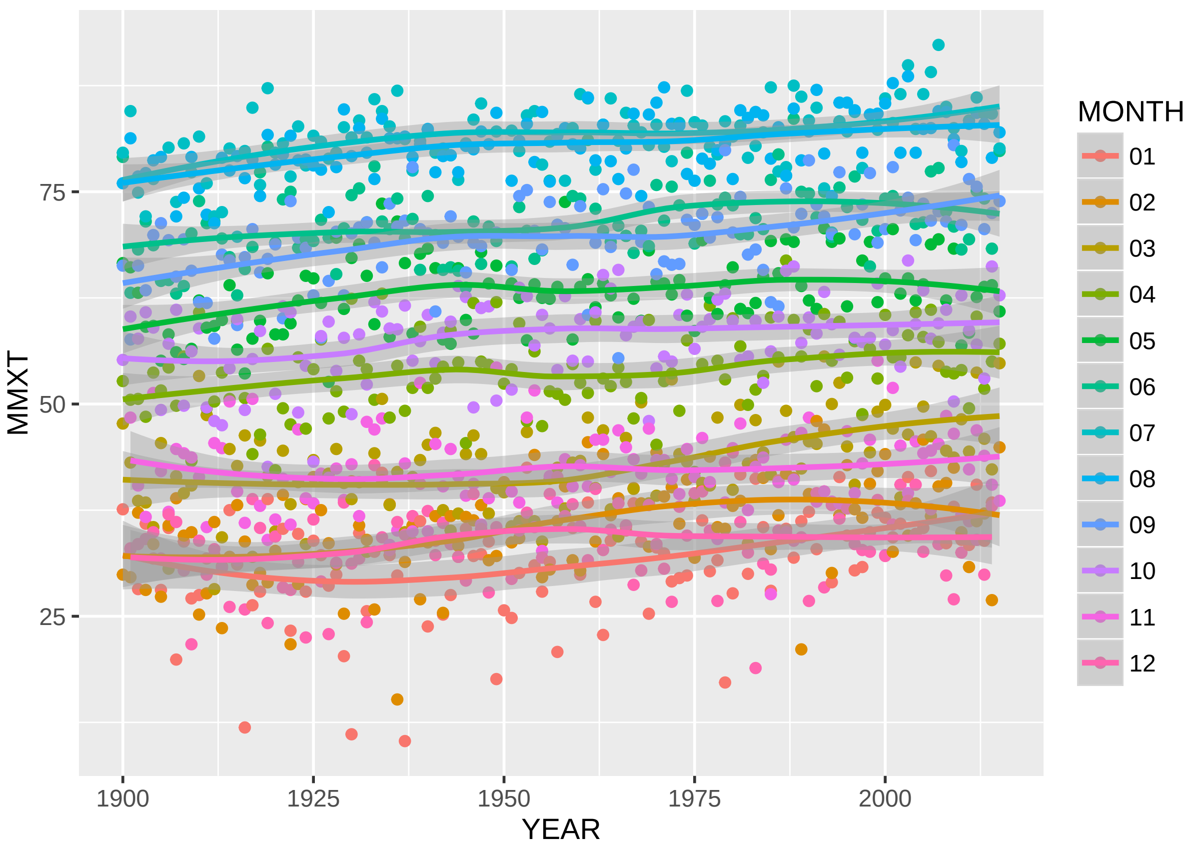
The model for January is as follows:

$$\widehat{temp_i} = -69.2902 + 0.0517 \text{ Year}_i$$

The model for July is as follows:

$$\widehat{temp_i} = -19.6994 + 0.0517 \text{ Year}_i$$

3.



It appears that December and November average temperatures have not changed much from 1900 to 2015, while January and March appear to have the most substantial increases over the 115 year period. It appears that average monthly temperature increased about 5 ° F over the 115 years, which is quite similar to the average rate of increase we discussed in the Oregon State temperature data in class.

4.

Below is the ANOVA table for testing if the the effect of time differs by month, using Type II sums of squares. We see in the table that there is strong evidence that the relationship between time and the mean temperature differs by month (F-stat = 2.1295 on an F(11, 1350) distribution, p-value = 0.016).

Table 1: Anova Table (Type II tests)

	Sum Sq	Df	F value	Pr(>F)
YEAR	4108	1	196.1	1.034e-41
MONTH	408393	11	1773	0
YEAR:MONTH	490.6	11	2.129	0.01603
Residuals	28276	1350	NA	NA

5.

```
  01   02   03   04   05   06   07   08   09   10   11   12
 "a"  "b"  "c"  "d"  "f"  "h"  "i"  "i"  "g"  "e"  "c" "ab"
```

```
     Simultaneous Confidence Intervals

Multiple Comparisons of Means: Tukey Contrasts


Fit: lm(formula = MMXT ~ YEAR + MONTH, data = rawd2)

Quantile = 3.2707
95% family-wise confidence level


Linear Hypotheses:
             Estimate  lwr       upr
02 - 01 == 0   3.70575   1.72701   5.68450
03 - 01 == 0  11.19799   9.21925  13.17674
04 - 01 == 0  21.99024  20.01149  23.96898
05 - 01 == 0  31.24123  29.25820  33.22425
06 - 01 == 0  39.72992  37.74690  41.71295
07 - 01 == 0  49.59080  47.59899  51.58261
08 - 01 == 0  48.49598  46.50858  50.48337
09 - 01 == 0  37.66381  35.67204  39.65559
10 - 01 == 0  25.86088  23.87352  27.84824
11 - 01 == 0  10.35817   8.37077  12.34557
12 - 01 == 0   1.78021  -0.21157   3.77199
03 - 02 == 0   7.49224   5.51779   9.46669
04 - 02 == 0  18.28448  16.31004  20.25893
05 - 02 == 0  27.53548  25.55674  29.51421
06 - 02 == 0  36.02417  34.04544  38.00291
07 - 02 == 0  45.88505  43.89753  47.87257
08 - 02 == 0  44.79023  42.80713  46.77332
09 - 02 == 0  33.95806  31.97055  35.94557
10 - 02 == 0  22.15513  20.17204  24.13822
11 - 02 == 0   6.65242   4.66932   8.63552
12 - 02 == 0  -1.92554  -3.91305   0.06197
04 - 03 == 0  10.79224   8.81779  12.76669
05 - 03 == 0  20.04323  18.06450  22.02197
06 - 03 == 0  28.53193  26.55319  30.51066
07 - 03 == 0  38.39281  36.40528  40.38033
08 - 03 == 0  37.29798  35.31489  39.28108
09 - 03 == 0  26.46582  24.47831  28.45333
10 - 03 == 0  14.66289  12.67980  16.64598
11 - 03 == 0  -0.83982  -2.82292   1.14328
12 - 03 == 0  -9.41778 -11.40529  -7.43027
05 - 04 == 0   9.25099   7.27226  11.22973
06 - 04 == 0  17.73969  15.76095  19.71842
07 - 04 == 0  27.60056  25.61304  29.58809
08 - 04 == 0  26.50574  24.52264  28.48884
09 - 04 == 0  15.67358  13.68607  17.66109
```

```
10 - 04 == 0   3.87065   1.88756   5.85374
11 - 04 == 0 -11.63206 -13.61516  -9.64896
12 - 04 == 0 -20.21002 -22.19753 -18.22251
06 - 05 == 0   8.48870   6.50568  10.47171
07 - 05 == 0  18.34957  16.35779  20.34135
08 - 05 == 0  17.25475  15.26739  19.24211
09 - 05 == 0   6.42259   4.43082   8.41436
10 - 05 == 0  -5.38035  -7.36771  -3.39299
11 - 05 == 0 -20.88306 -22.87042 -18.89569
12 - 05 == 0 -29.46101 -31.45278 -27.46925
07 - 06 == 0   9.86088   7.86910  11.85266
08 - 06 == 0   8.76605   6.77869  10.75342
09 - 06 == 0  -2.06611  -4.05788  -0.07434
10 - 06 == 0 -13.86904 -15.85640 -11.88168
11 - 06 == 0 -29.37175 -31.35912 -27.38439
12 - 06 == 0 -37.94971 -39.94148 -35.95794
08 - 07 == 0  -1.09482  -3.09092   0.90127
09 - 07 == 0 -11.92699 -13.92749  -9.92648
10 - 07 == 0 -23.72992 -25.72604 -21.73380
11 - 07 == 0 -39.23263 -41.22872 -37.23654
12 - 07 == 0 -47.81059 -49.81108 -45.81009
09 - 08 == 0 -10.83216 -12.82827  -8.83605
10 - 08 == 0 -22.63510 -24.62681 -20.64338
11 - 08 == 0 -38.13781 -40.12950 -36.14612
12 - 08 == 0 -46.71576 -48.71186 -44.71966
10 - 09 == 0 -11.80293 -13.79903  -9.80684
11 - 09 == 0 -27.30564 -29.30176 -25.30953
12 - 09 == 0 -35.88360 -37.88409 -33.88311
11 - 10 == 0 -15.50271 -17.49443 -13.51099
12 - 10 == 0 -24.08067 -26.07676 -22.08457
12 - 11 == 0  -8.57796 -10.57406  -6.58185
```

Using the above compact letter display, we see that the following months are not detectalbly different from each other, after accounting for the linear relationship between average temperatures and year.

- January and December
- February and December
- November and March

Overall, there is strong evidence that August and July were the warmest months on average and after accounting for yearly temperature changes. There was strong evidence that June was the next warmest, followed by September, then May, then October, then April, then March, and then November on average and after accounting for yearly temperature changes. There is strong evidence that December and Feburary were the coolest months on average and after accounting for yearly temperature changes with no evidence of a difference between January and December under similar model conditions.

6.

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-316	477	-0.663	0.507
MONTH02	3.71	0.605	6.13	1.18e-09

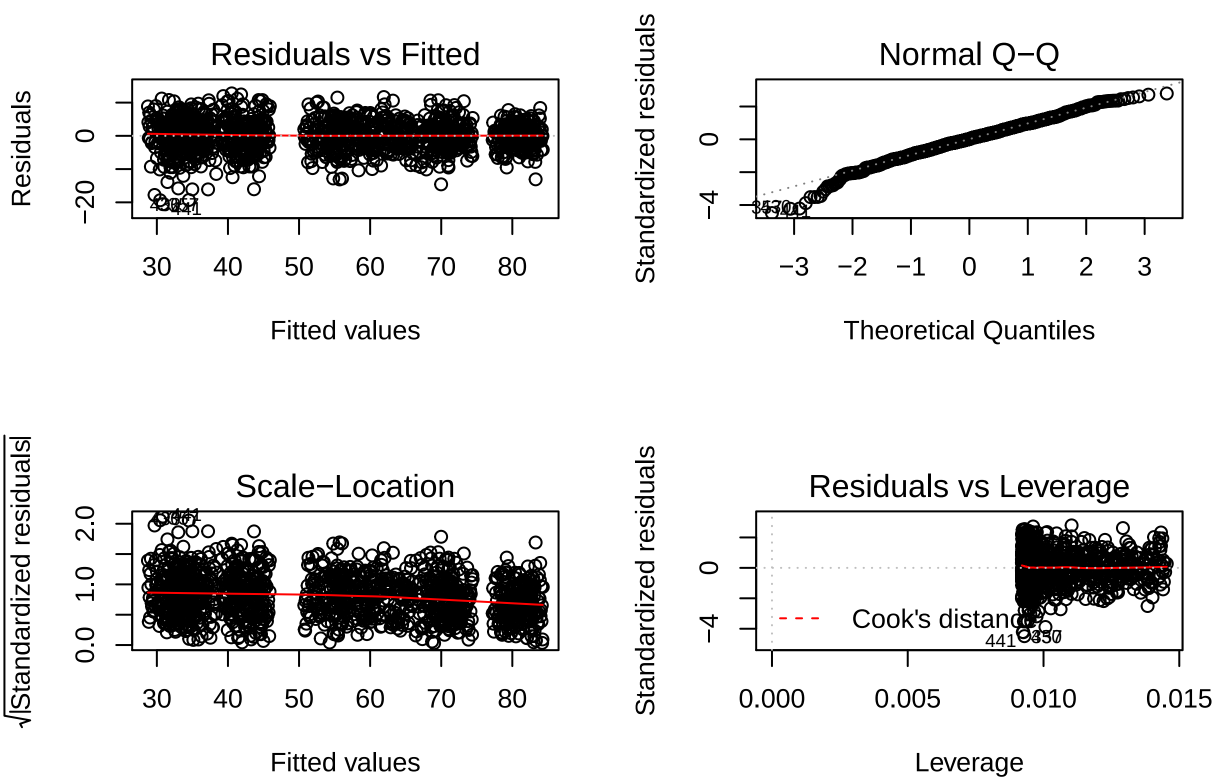
	Estimate	Std. Error	t value	Pr(>|t|)
MONTH03	11.2	0.605	18.5	2.24e-68
MONTH04	22	0.605	36.3	1.24e-202
MONTH05	31.2	0.606	51.5	6.32e-322
MONTH06	39.7	0.606	65.5	0
MONTH07	49.6	0.609	81.4	0
MONTH08	48.5	0.608	79.8	0
MONTH09	37.7	0.609	61.8	0
MONTH10	25.9	0.608	42.6	3.03e-252
MONTH11	10.4	0.608	17	3.5e-59
MONTH12	1.78	0.609	2.92	0.00354
YEAR	0.304	0.487	0.624	0.533
I(YEAR^2)	-6.45e-05	0.000125	-0.518	0.604

Testing for evidence of a quadratic relationship between average temperatures and year, after accounting for monthly variation and a linear year trend, we have the following hypothesis:

$H_0 : \beta_{year^2} = 0$ $H_A : \beta_{year^2} \neq 0$

Using the above model output, there is no evidence of a quadratic relationship between average temperatures and year, after accounting for monthly variation and a linear year trend (t-stat = -0.518 $\sim t_{1360}$, p-value = 0.604).

7.



The monthly discreteness is apparent in the clumps in the residuals vs. fitted plot. It does appear that there is less spread in the larger fitted values than the smaller. Hence, the fitted values for the summer months show less variability than the fitted values for the cooler months. We also note the scale of the residuals, with residuals near -20 occurring in the cooler months. Observation 441, a January measurement in 1937 with a MMXT of 10.3, differs from all other January measurements by nearly 10 units.

8.

```r
## Allison's R Version
getRversion()
```

```
## [1] '3.3.1'
```