Homework3 - Ganapathy Raaman Balaji

Question 7.1

Describe a situation or problem from your job, everyday life, current events, etc., for which exponential smoothing would be appropriate. What data would you need? Would you expect the value of α (the first smoothing parameter) to be closer to 0 or 1, and why?

As an Analytics Engineer, I look at time series data every day. Most of the data has some sort of seasonality and trend. Currently I am working on a project where I am summarizing the operation performance of a drill engine. The seasonality is almost always additive in most of the data I have looked at in the past 3 years.

The data collection frequency varies from 1Hz to as much as 100Hz. Even for the same recorded data, sometimes the Control Module records data at a different sample rate. I have built exponential smoothing models to look at the engine loading trend with respect to time. Along with aftertreatment and sometimes machine channels, the model helps understand the engine performance.

To start with a baseline model, I tend to use the previous value to estimate the current value of a calculated channel. I end up usin g alpha = 1.

```
In [ ]:
```

Question 7.2

Using the 20 years of daily high temperature data for Atlanta (July through October) from Question 6.2 (file temps.txt), build and use an exponential smoothing model to help make a judgment of whether the unofficial end of summer has gotten later over the 20 years. (Part of the point of this assignment is for you to think about how you might use exponential smoothing to answer this question. Feel free to combine it with other models if you'd like to. There's certainly more than one reasonable approach.)

Note: in R, you can use either HoltWinters (simpler to use) or the smooth package's es function (harder to use, but more general). If you use es, the Holt-Winters model uses model="AAM" in the function call (the first and second constants are used "A"dditively, and the third (seasonality) is used "M"ultiplicatively; the documentation doesn't make that clear).

```
In [1]: # install.packages("forecast", repos='http://cran.us.r-project.org')
    # install.packages("xlsx", repos='http://cran.us.r-project.org')
    suppressWarnings(suppressMessages(library("TTR")))
    suppressWarnings(suppressMessages(library("forecast")))

In [6]: # install.packages("xlsx", repos='http://cran.us.r-project.org')
    suppressWarnings(suppressMessages(require(xlsx)))
```

Firstly, read the text file, flatten the data frame to a single vector (time series data of frequency = 1 day).

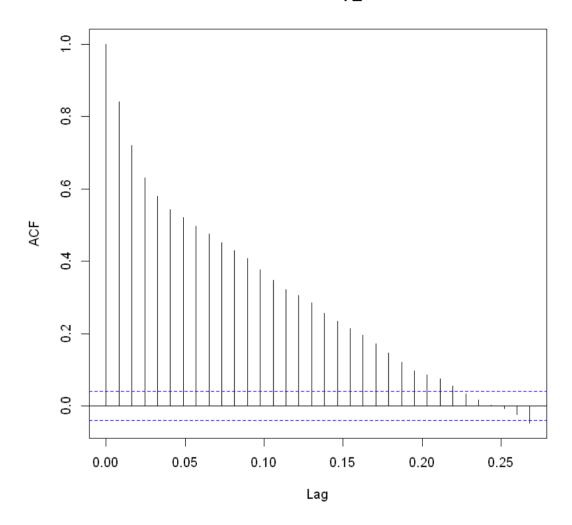
```
In [7]: temperature <- read.table("temps.txt", header = T, sep = '\t')
    temp_vector <- as.vector(unlist(temperature[,2:21], recursive = TRUE, use.names = TRUE))

# There are 123 days of data. We want frequency of 1 day. So, deLtat = 1/123
    temp_ts <- ts(temp_vector, start=c(1996,1), end = c(2015,123), deltat = 1/123)</pre>
In [8]: str(temp_ts)

Time-Series [1:2460] from 1996 to 2016: 98 97 97 90 89 93 93 91 93 93 ...
```

```
In [9]: # Auto Correlation plot showing that only one value lying outside the 95% limits and
# the L-jung box test has a p-value < 2.2e-16
acf(temp_ts, lag.max = NULL, type = "correlation",plot = TRUE)</pre>
```

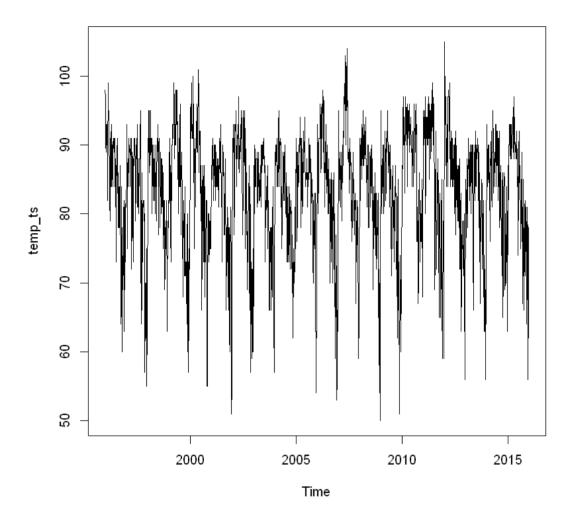
Series temp_ts



```
In [10]: Box.test(temp_ts, lag = 10, type = "Ljung-Box", fitdf = 0)
Box-Ljung test
```

data: temp_ts
X-squared = 8350.9, df = 10, p-value < 2.2e-16</pre>

In [11]: # Plotting the time series data
plot.ts(temp_ts)



Now I am going to decompose the time series data, separating it into its constituent components, which are trend component and an irregular component, and if it is a seasonal time series, a seasonal component.

```
In [12]: temp_components <- decompose(temp_ts)
    temp_components$seasonal
    autoplot(temp_components)</pre>
```

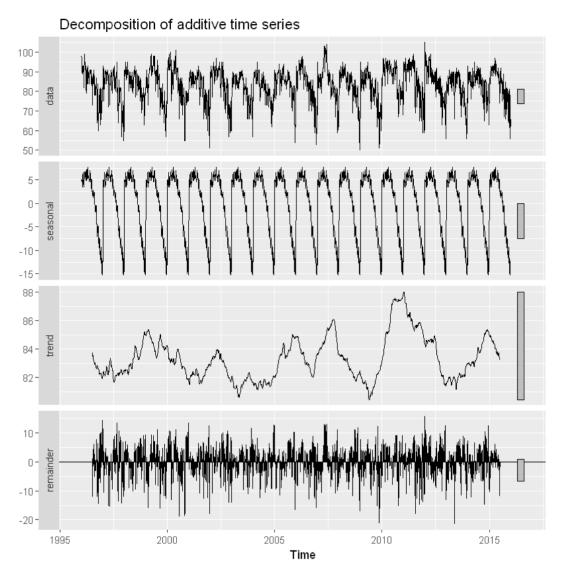
Time Series: Start = c(1996, 1)End = c(2015, 123)Frequency = 123[1] 5 0322211 4 5555416 4 6008989 4 9158326 4 8597778 4 2281989 3,4404368 5.7053063 6.5495511 4.9723153 4,4982032 4,6560979 [7] Γ**1**31 3.5551137 4.6090290 3.9256743 4.6124522 5.5084727 5.6133080 6.7690632 5.5551137 6.5508348 5.8144205 5.6060337 5.5546858 [19] [25] 4.8747543 6.4622597 6.6257171 7.2080876 5.8922982 6.1533166 4 8811728 5.3527175 6.5208818 6 9419345 [31] 5,2500217 7 7284128 [37] 6.1443307 5.5037659 5,6599490 5,6026105 5.9188279 5.9171163 4.6509631 5.0690205 5.3860936 5.6017547 **[43]** 4.9633294 4.5953362 [49] 6.7596495 6.9697479 5.9684642 5.7065900 5.9706037 4.9128373 [55] 4.3326063 3,2808305 5.1263589 4.4502785 3.8726148 4.9830128 [61] 2 5670949 2 5606764 1 8221227 1 6685070 2 4130513 2 1520329 [67] 2.8383829 1.2632866 1,4224650 2.0018403 1.6342751 1.9500645 73 2.2123666 2.3694056 0.2119387 0.6869066 0.5786482 -0.8937523 -1.6806586 -0.6233201 [79] -1.5240476 -1.1522033 -1.4662812 -1.8334186 -0.4637138 -2.5681212 -3.3601623 -4.3631575 -4.3674365 -4.4791182 Γ851 -6.7448435 [91] -7.0067177 -5.9053056 -5.8013261 -5.0135641 -5.0704746 [97] -4.8625157 -6.9686347 -8.0212662 -8.9147194 -9 ////58/ -7.9720578 [103] -7.3426184 -7.5544284 -8.1877190 -9.3477532 -10.8757806 -10.9288400 -10.0867348 -11.1385106 -11.9267006 [109] -12.0841674 -9.3468974 -11.3464695 [115] -14.2942658 -14.8715016 -14.0811721 -11.7127510 -13.7645268 -15.2386389 -14.0268289 -12.2343599 -12.3879757 Γ1211 5.0322211 4.5555416 4.6008989 4.8597778 6.5495511 [127] 4.9158326 4.2281989 3,4404368 5.7053063 Γ1331 4.9723153 4.4982032 4,6560979 3.5551137 4.6090290 3.9256743 [139] 4.6124522 5.5084727 5.6133080 6.7690632 5.5551137 6.5508348 5.8144205 Ī145Ī 5,6060337 5.5546858 4.8747543 6.4622597 6.6257171 7.2080876 5.8922982 6.1533166 4.8811728 5.3527175 5.2500217 **[151]** 6.5208818 6.9419345 5.6599490 [157] 7.7284128 6.1443307 5.5037659 [163] 5.6026105 5.9188279 5.9171163 4.6509631 4.9633294 5.0690205 [169] 4.5953362 5.3860936 5.6017547 6.7596495 6.9697479 5.9684642 [175] 5.7065900 5.9706037 4.9128373 4.3326063 3.2808305 5.1263589 [181] 4.4502785 3.8726148 4.9830128 2.5670949 2.5606764 1.8221227 1,6685070 2.4130513 2.8383829 1,4224650 [187] 2.1520329 1,2632866 [193] 2,0018403 1,6342751 1 9500645 2.2123666 2 3694056 0 2119387 [199] 0.6869066 0.5786482 -0.8937523 -1.5240476 -1.6806586 -1.1522033 [205] -0.6233201 -1.4662812 -1.8334186 -0.4637138 -2.5681212 -3.3601623 [211] -4.3631575 -4.3674365 -4.4791182 -7.0067177 -6.7448435 -5.9053056 -5.0135641 -5.0704746 -6.9686347 Γ2171 -5.8013261 -4.8625157 -8.0212662 [223] -9.4444584 -7.9720578 -7.5544284 -8.9147194 -7.3426184 -8.1877190 [229] -9.3477532 -10.8757806 -10.9288400 -10.0867348 -11.1385106 -11.9267006 [235] -12.0841674 -9.3468974 -11.3464695 -14.2942658 -14.8715016 -14.0811721 -11.7127510 -13.7645268 [241] -15.2386389 -14.0268289 -12.2343599 -12.3879757 [247] 5.0322211 4.5555416 4.6008989 4.9158326 4.8597778 4.2281989 [253] 3.4404368 5.7053063 6.5495511 4.4982032 4.9723153 4.6560979 [259] 3.5551137 4,6090290 3.9256743 4.6124522 5.5084727 5.6133080 [265] 6.7690632 5.5551137 6.5508348 5.8144205 5,6060337 5.5546858 4.8747543 6.4622597 6.6257171 7.2080876 5.8922982 6.1533166 [271] [277] 4.8811728 5.3527175 5.2500217 6.5208818 6.9419345 7.7284128 [283] 6.1443307 5.5037659 5.6599490 5.6026105 5.9188279 5.9171163 4.5953362 [289] 4.6509631 4.9633294 5.0690205 5.3860936 5.6017547 [295] 6.7596495 6.9697479 5.9684642 5.7065900 5.9706037 4.9128373 [301] 4.3326063 3.2808305 5.1263589 4.4502785 3.8726148 4.9830128 [307] 2.5670949 2.5606764 1.8221227 1.6685070 2.4130513 2.1520329 2.8383829 1.2632866 1.4224650 2.0018403 1.6342751 1.9500645 [313] 2.3694056 0.2119387 0.6869066 -0.8937523 [319] 2.2123666 0.5786482 -1.6806586 -0.6233201 -1,4662812 [325] -1.5240476 -1.1522033 -1.8334186 [331] -0.4637138 -2.5681212 -3.3601623 -4.3631575 -4.3674365 -4.4791182 -5.9053056 -5.0704746 [337] -7.0067177 -6.7448435 -5.8013261 -5.0135641 [343] -4.8625157 -6.9686347 -8.0212662 -8.9147194 -9.4444584 -7.9720578 [349] -7.3426184 -7.5544284 -8.1877190 -9.3477532 -10.8757806 -10.9288400 [355] -10.0867348 -11.1385106 -11.9267006 -12.0841674 -9.3468974 -11.3464695 [361] -14.2942658 -14.8715016 -14.0811721 -11.7127510 -13.7645268 -15.2386389 [367] -14.0268289 -12.2343599 -12.3879757 5.0322211 4.5555416 4.6008989 [373] 4.9158326 4.8597778 4.2281989 3.4404368 5.7053063 6.5495511 [379] 4.9723153 4.4982032 4.6560979 3.9256743 3,5551137 4,6090290 5.5084727 5,6133080 6.7690632 5.5551137 [385] 4,6124522 6.5508348 [391] 5.8144205 5,6060337 5.5546858 4.8747543 6.4622597 6.6257171 5.2500217 [397] 7.2080876 5.8922982 6.1533166 4.8811728 5.3527175 [403] 6.5208818 6.9419345 7,7284128 6.1443307 5.5037659 5,6599490 [409] 5.6026105 5.9188279 5.9171163 4.6509631 4.9633294 5.0690205 [415] 4.5953362 5.3860936 5.6017547 6.7596495 6.9697479 5.9684642 5.9706037 [421] 5.7065900 4.9128373 4.3326063 3.2808305 5.1263589 [427] 4.4502785 3.8726148 4.9830128 2.5670949 2.5606764 1.8221227 [433] 1.6685070 2.4130513 2.1520329 2.8383829 1.2632866 1.4224650 [439] 2.0018403 1.6342751 1.9500645 2.2123666 2.3694056 0.2119387 0.6869066 -0.8937523 -1.5240476 -1.6806586 [445] 0.5786482 -1.1522033 Γ4511 -0.6233201 -1.4662812 -1.8334186 -0.4637138 -2.5681212 -3.3601623 [457] -4.3631575 -4.3674365 -4.4791182 -7.0067177 -6.7448435 -5.9053056 [463] -5.8013261 -5.0135641 -5.0704746 -4.8625157 -6.9686347 -8.0212662 [469] -8.9147194 -9.4444584 -7.9720578 -7.3426184 -7.5544284 -8.1877190 [475] -9.3477532 -10.8757806 -10.9288400 -10.0867348 -11.1385106 -11.9267006 [481] -12.0841674 -9.3468974 -11.3464695 -14.2942658 -14.8715016 -14.0811721 [487] -11.7127510 -13.7645268 -15.2386389 -14.0268289 -12.2343599 -12.3879757

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[493]	5.0322211	4.5555416	4.6008989	4.9158326	4.8597778	4.2281989
[499]		5.7053063	6.5495511	4.9723153	4.4982032	4.6560979
[505]		4.6090290	3.9256743	4.6124522	5.5084727	5.6133080
[511]	6.7690632	5.5551137	6.5508348	5.8144205	5.6060337	5.5546858
[517]		6.4622597	6.6257171	7.2080876	5.8922982	6.1533166
[523]		5.3527175	5.2500217	6.5208818	6.9419345	7.7284128
[529]		5.5037659	5.6599490	5.6026105	5.9188279	5.9171163
[535]	4.6509631	4.9633294	5.0690205	4.5953362	5.3860936	5.6017547
[541]	6.7596495	6.9697479	5.9684642	5.7065900	5.9706037	4.9128373
[547]		3.2808305	5.1263589	4.4502785	3.8726148	4.9830128
[553]		2.5606764	1.8221227	1.6685070	2.4130513	2.1520329
[559]		1.2632866	1.4224650	2.0018403	1.6342751	1.9500645
[565]	2.2123666	2.3694056	0.2119387	0.6869066	0.5786482	-0.8937523
[571]	-1.5240476	-1.6806586	-1.1522033	-0.6233201	-1.4662812	-1.8334186
[577]	-0.4637138	-2.5681212	-3.3601623	-4.3631575	-4.3674365	-4.4791182
[583]		-6.7448435	-5.9053056	-5.8013261	-5.0135641	-5.0704746
[589]		-6.9686347	-8.0212662	-8.9147194	-9.4444584	-7.9720578
[595]	-7.3426184	-7.5544284	-8.1877190	-9.3477532	-10.8757806	-10.9288400
[601]	-10.0867348	-11.1385106	-11.9267006	-12.0841674	-9.3468974	-11.3464695
[607]	-14.2942658	-14.8715016	-14.0811721	-11.7127510	-13.7645268	-15.2386389
[613]		-12.2343599		5.0322211	4.5555416	4.6008989
[619]		4.8597778	4.2281989	3.4404368	5.7053063	6.5495511
[625]	4.9723153	4.4982032	4.6560979	3.5551137	4.6090290	3.9256743
[631]	4.6124522	5.5084727	5.6133080	6.7690632	5.5551137	6.5508348
[637]	5.8144205	5.6060337	5.5546858	4.8747543	6.4622597	6.6257171
[643]		5.8922982	6.1533166	4.8811728	5.3527175	5.2500217
			7.7284128			
[649]		6.9419345		6.1443307	5.5037659	5.6599490
[655]		5.9188279	5.9171163	4.6509631	4.9633294	5.0690205
[661]	4.5953362	5.3860936	5.6017547	6.7596495	6.9697479	5.9684642
[667]	5.7065900	5.9706037	4.9128373	4.3326063	3.2808305	5.1263589
[673]		3.8726148	4.9830128	2.5670949	2.5606764	1.8221227
[679]		2.4130513	2.1520329	2.8383829	1.2632866	
						1.4224650
[685]		1.6342751	1.9500645	2.2123666	2.3694056	0.2119387
[691]	0.6869066	0.5786482	-0.8937523	-1.5240476	-1.6806586	-1.1522033
[697]	-0.6233201	-1.4662812	-1.8334186	-0.4637138	-2.5681212	-3.3601623
[703]	-4.3631575	-4.3674365	-4.4791182	-7.0067177	-6.7448435	-5.9053056
[709]		-5.0135641	-5.0704746	-4.8625157	-6.9686347	-8.0212662
			-7.9720578	-7.3426184		
[715]		-9.4444584			-7.5544284	-8.1877190
[721]		-10.8757806			-11.1385106	
[727]	-12.0841674	-9.3468974	-11.3464695	-14.2942658	-14.8715016	-14.0811721
[733]	-11.7127510	-13.7645268	-15.2386389	-14.0268289	-12.2343599	-12.3879757
739	5.0322211	4.5555416	4.6008989	4.9158326	4.8597778	4.2281989
[745]		5.7053063	6.5495511	4.9723153	4.4982032	4.6560979
[751]		4.6090290	3.9256743	4.6124522	5.5084727	5.6133080
[757]	6.7690632	5.5551137	6.5508348	5.8144205	5.6060337	5.5546858
[763]	4.8747543	6.4622597	6.6257171	7.2080876	5.8922982	6.1533166
[769]	4.8811728	5.3527175	5.2500217	6.5208818	6.9419345	7.7284128
[775]		5.5037659	5.6599490	5.6026105	5.9188279	5.9171163
		4.9633294	5.0690205	4.5953362	5.3860936	5.6017547
[781]						
[787]	6.7596495				5.9706037	4.9128373
[793]		6.9697479	5.9684642	5.7065900		
[,,,,]		3.2808305	5.9684642 5.1263589	4.4502785	3.8726148	4.9830128
[799]	4.3326063					
[799]	4.3326063 2.5670949	3.2808305 2.5606764	5.1263589 1.8221227	4.4502785 1.6685070	3.8726148 2.4130513	4.9830128 2.1520329
[799] [805]	4.3326063 2.5670949 2.8383829	3.2808305 2.5606764 1.2632866	5.1263589 1.8221227 1.4224650	4.4502785 1.6685070 2.0018403	3.8726148 2.4130513 1.6342751	4.9830128 2.1520329 1.9500645
[799] [805] [811]	4.3326063 2.5670949 2.8383829 2.2123666	3.2808305 2.5606764 1.2632866 2.3694056	5.1263589 1.8221227 1.4224650 0.2119387	4.4502785 1.6685070 2.0018403 0.6869066	3.8726148 2.4130513 1.6342751 0.5786482	4.9830128 2.1520329 1.9500645 -0.8937523
[799] [805] [811] [817]	4.3326063 2.5670949 2.8383829 2.2123666 -1.5240476	3.2808305 2.5606764 1.2632866 2.3694056 -1.6806586	5.1263589 1.8221227 1.4224650 0.2119387 -1.1522033	4.4502785 1.6685070 2.0018403 0.6869066 -0.6233201	3.8726148 2.4130513 1.6342751 0.5786482 -1.4662812	4.9830128 2.1520329 1.9500645 -0.8937523 -1.8334186
[799] [805] [811] [817] [823]	4.3326063 2.5670949 2.8383829 2.2123666 -1.5240476 -0.4637138	3.2808305 2.5606764 1.2632866 2.3694056 -1.6806586 -2.5681212	5.1263589 1.8221227 1.4224650 0.2119387 -1.1522033 -3.3601623	4.4502785 1.6685070 2.0018403 0.6869066 -0.6233201 -4.3631575	3.8726148 2.4130513 1.6342751 0.5786482 -1.4662812 -4.3674365	4.9830128 2.1520329 1.9500645 -0.8937523 -1.8334186 -4.4791182
[799] [805] [811] [817] [823]	4.3326063 2.5670949 2.8383829 2.2123666 -1.5240476 -0.4637138 -7.0067177	3.2808305 2.5606764 1.2632866 2.3694056 -1.6806586 -2.5681212 -6.7448435	5.1263589 1.8221227 1.4224650 0.2119387 -1.1522033 -3.3601623 -5.9053056	4.4502785 1.6685070 2.0018403 0.6869066 -0.6233201 -4.3631575 -5.8013261	3.8726148 2.4130513 1.6342751 0.5786482 -1.4662812 -4.3674365 -5.0135641	4.9830128 2.1520329 1.9500645 -0.8937523 -1.8334186 -4.4791182 -5.0704746
[799] [805] [811] [817] [823]	4.3326063 2.5670949 2.8383829 2.2123666 -1.5240476 -0.4637138 -7.0067177	3.2808305 2.5606764 1.2632866 2.3694056 -1.6806586 -2.5681212	5.1263589 1.8221227 1.4224650 0.2119387 -1.1522033 -3.3601623	4.4502785 1.6685070 2.0018403 0.6869066 -0.6233201 -4.3631575	3.8726148 2.4130513 1.6342751 0.5786482 -1.4662812 -4.3674365	4.9830128 2.1520329 1.9500645 -0.8937523 -1.8334186 -4.4791182
[799] [805] [811] [817] [823] [829] [835]	4.3326063 2.5670949 2.8383829 2.2123666 -1.5240476 -0.4637138 -7.0067177 -4.8625157	3.2808305 2.5606764 1.2632866 2.3694056 -1.6806586 -2.5681212 -6.7448435	5.1263589 1.8221227 1.4224650 0.2119387 -1.1522033 -3.3601623 -5.9053056	4.4502785 1.6685070 2.0018403 0.6869066 -0.6233201 -4.3631575 -5.8013261 -8.9147194	3.8726148 2.4130513 1.6342751 0.5786482 -1.4662812 -4.3674365 -5.0135641	4.9830128 2.1520329 1.9500645 -0.8937523 -1.8334186 -4.4791182 -5.0704746 -7.9720578
[799] [805] [811] [817] [823] [829] [835] [841]	4.3326063 2.5670949 2.8383829 2.2123666 -1.5240476 -0.4637138 -7.0067177 -4.8625157 -7.3426184	3.2808305 2.5606764 1.2632866 2.3694056 -1.6806586 -2.5681212 -6.7448435 -6.9686347 -7.5544284	5.1263589 1.8221227 1.4224650 0.2119387 -1.1522033 -3.3601623 -5.9053056 -8.0212662 -8.1877190	4.4502785 1.6685070 2.0018403 0.6869066 -0.6233201 -4.3631575 -5.8013261 -8.9147194 -9.3477532	3.8726148 2.4130513 1.6342751 0.5786482 -1.466281 -4.3674365 -5.0135641 -9.4444584 -10.8757806	4.9830128 2.1520329 1.9500645 -0.8937528 -1.8334126 -4.4791182 -5.6704746 -7.9720578 -10.9288400
[799] [805] [811] [817] [823] [829] [835] [841] [847]	4.3326063 2.5670949 2.8383829 2.2123666 -1.5240476 -0.4637138 -7.0067177 -4.8625157 -7.3426184 -10.0867348	3.2808305 2.5606764 1.2632866 2.3694056 -1.6806586 -2.5681212 -6.7448435 -6.9686347 -7.5544284 -11.1385106	5.1263589 1.8221227 1.4224650 0.2119387 -1.1522033 -3.3601623 -5.9053056 -8.0212662 -8.1877190 -11.9267006	4.4502785 1.6685070 2.0018403 0.6869066 -0.6233201 -4.3631575 -5.8013261 -8.9147194 -9.3477532 -12.0841674	3.8726148 2.4130513 1.6342751 0.5786482 -1.4662812 -4.3674365 -5.0135641 -9.4444584 -10.8757806 -9.3468974	4.9830128 2.1520329 1.9500645 -0.8937523 -1.8334186 -4.4791182 -5.0704746 -7.9720578 -10.9288400 -11.3464695
[799] [805] [811] [817] [823] [829] [835] [841] [847] [853]	4.3326063 2.5670949 2.8383829 2.2123666 -1.5240476 -0.4637138 -7.0067177 -4.8625157 -7.3426184 -10.0867348 -14.2942658	3.2808305 2.5606764 1.2632866 2.3694056 -1.6806586 -2.568121 -6.7448435 -6.9686347 -7.5544284 -11.1385106 -14.8715016	5.1263589 1.8221227 1.4224650 0.2119387 -1.1522033 -3.3601623 -5.9053056 -8.0212662 -8.1877190 -11.9267006 -14.0811721	4.4502785 1.6685070 2.0018403 0.6869066 -0.6233201 -4.3631575 -5.8013261 -8.9147194 -9.3477532 -12.0841674 -11.7127510	3.8726148 2.4130513 1.6342751 0.5786482 -1.4662812 -4.3674365 -5.0135641 -9.4444584 -10.8757806 -9.3468974 -13.7645268	4.9830128 2.1520329 1.9500645 -0.8937523 -1.8334186 -4.4791182 -5.0704746 -7.9720578 -10.9288400 -11.3464695 -15.2386389
[799] [805] [811] [817] [823] [829] [835] [841] [847] [853] [859]	4.3326063 2.5670949 2.838832 2.2123666 -1.5240476 -0.4637138 -7.0067177 -4.8625157 -7.3426184 -10.0867348 -14.2942658	3.2808305 2.5606764 1.2632866 2.3694056 -1.6806586 -2.5681212 -6.7448435 -6.9686347 -7.5544284 -11.1385106 -14.8715016 -12.2343599	5.1263589 1.8221227 1.4224650 0.2119387 -1.1522033 -3.3601623 -5.9053056 -8.0212662 -8.1877190 -11.9267006 -14.0811721 -12.3879757	4.4502785 1.6685070 2.0018403 0.6869066 -0.6233201 -4.3631575 -5.8013261 -8.9147194 -9.347753 -12.0841674 -11.7127510 5.0322211	3.8726148 2.4130513 1.6342751 1.5786482 -1.4662812 -4.3674365 -5.0135641 -9.4444584 -10.8757806 -9.3468974 -13.7645268 4.5555416	4.9830128 2.1520329 1.9500645 -0.8937523 -1.8334186 -4.4791182 -5.0704746 -7.9720578 -10.9288400 -11.3464695 -15.2386389 4.6008989
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[799] [805] [811] [817] [823] [829] [835] [841] [847] [853] [859]	4.3326063 2.5670949 2.8383829 2.2123666 -1.5240476 -0.4637138 -7.0067177 -4.8625157 -7.3426184 -10.0867348 -14.2942658 -14.0268289 4.9158326	3.2808305 2.5606764 1.2632866 2.3694056 -1.6806586 -2.5681212 -6.7448435 -6.9686347 -7.5544284 -11.1385106 -14.8715016 -12.2343599	5.1263589 1.8221227 1.4224650 0.2119387 -1.1522033 -3.3601623 -5.9053056 -8.0212662 -8.1877190 -11.9267006 -14.0811721 -12.3879757	4.4502785 1.6685070 2.0018403 0.6869066 -0.6233201 -4.3631575 -5.8013261 -8.9147194 -9.347753 -12.0841674 -11.7127510 5.0322211	3.8726148 2.4130513 1.6342751 1.5786482 -1.4662812 -4.3674365 -5.0135641 -9.4444584 -10.8757806 -9.3468974 -13.7645268 4.5555416	4.9830128 2.1520329 1.9500645 -0.8937523 -1.8334186 -4.4791182 -5.0704746 -7.9720578 -10.9288400 -11.3464695 -15.2386389 4.6008989
[799] [805] [811] [817] [823] [829] [835] [841] [847] [853] [859]	4.3326063 2.5670949 2.8383829 2.2123666 -1.5240476 -0.4637138 -7.0067177 -4.8625157 -7.3426184 -10.0867348 -14.2942658 -14.0268289 4.9158326 4.9723153	3.2808305 2.5606764 1.2632866 2.3694056 -1.6806586 -2.5681212 -6.7448435 -6.9686347 -7.5544284 -11.1385106 -14.8715016 -12.2343599 4.8597778	5.1263589 1.8221227 1.4224650 0.2119387 -1.1522033 -3.3601623 -5.9053056 -8.0212662 -8.1877190 -11.9267006 -14.0811721 -12.3879757 4.2281989	4.4502785 1.6685070 2.0018403 0.6869066 -0.6233201 -4.3631575 -5.8013261 -8.9147194 -9.3477532 -12.084167 -11.7127510 5.0322211 3.4404368	3.8726148 2.4130513 1.6342751 0.5786482 -1.4662812 -4.3674365 -5.0135641 -9.4444584 -10.8757806 -9.3468974 -13.7645268 4.5555416 5.7053063	4.9830128 2.1520329 1.9500645 -0.8937523 -1.8334186 -4.4791182 -5.0704746 -7.9720578 -10.9288400 -11.3464695 -15.2386389 4.6008989 6.5495511
[799] [805] [811] [817] [823] [829] [835] [841] [847] [853] [859] [865] [871]	4.3326063 2.5670949 2.8383829 2.2123666 -1.5240476 -0.4637138 -7.0067177 -4.8625157 -7.3426184 -10.0867348 -14.2942658 -14.0268289 4.9158326 4.9723153 4.6124522	3.2808305 2.5606764 1.2632866 2.3694056 -1.6806586 -2.5681212 -6.7448435 -6.9686347 -7.5544284 -11.1385106 -14.8715016 -12.2343599 4.88597778 4.4982032 5.5084727	5.1263589 1.8221227 1.4224650 0.2119387 -1.1522033 -3.3601623 -5.9053056 -8.0212662 -8.1877190 -11.9267006 -14.081172 -12.3879757 4.2281989 4.6560979 5.6133080	4.4502785 1.6685070 2.0018403 0.6869066 -0.6233201 -4.3631575 -5.8013261 -8.9147194 -9.3477532 -12.0841674 -11.7127510 5.0322211 3.4404368 3.5551137 6.7690632	3.8726148 2.4130513 1.6342751 0.5786482 -1.4662812 -4.3674365 -5.0135641 -9.4444584 -10.8757806 -9.3468974 -13.7645268 4.5555416 5.7053063 4.6090290 5.5551137	4.9830128 2.1520329 1.9500645 -0.8937523 -1.8834186 -4.4791182 -5.6704746 -7.9720578 -10.9288400 -11.3464695 -15.2386389 4.6008989 6.5495511 3.9256743 6.5508348
[799] [805] [811] [817] [823] [829] [835] [841] [853] [859] [857] [877] [883]	4.3326063 2.5670949 2.8383829 2.2123666 -1.5240476 -0.4637138 -7.0067177 -4.8625157 -7.3426184 -10.0867348 -14.2942658 -14.0268289 4.9158326 4.9723153 4.6124522 5.8144205	3.2808305 2.5606764 1.2632866 2.3694056 -1.6806586 -2.5681212 -6.7448435 -6.9686347 -7.5544284 -11.1385106 -14.8715016 -12.2343599 4.8597778 4.4982032 5.5084727 5.6060337	5.1263589 1.8221227 1.4224650 0.2119387 -1.1522033 -3.3601623 -5.9653056 -8.0212662 -8.1877190 -11.9267006 -14.0811721 -12.3879757 4.2281989 4.6560979 5.6133080 5.5546858	4.4502785 1.6685070 2.0018403 0.6869066 -0.6233201 -4.3631575 -5.8013261 -8.9147194 -9.3477532 -12.0841674 -11.7127510 5.0322211 3.4404368 3.5551137 6.7690632 4.8747543	3.8726148 2.4130513 1.6342751 0.5786482 -1.4662815 -5.0135641 -9.4444584 -10.8757806 -9.3468974 -13.7645268 4.5555415 5.7053063 4.6090290 5.5551137 6.4622597	4.9830128 2.1520329 1.9500645 -0.8937523 -1.8334186 -4.4791182 -5.0704746 -7.9720578 -10.9288400 -11.3464695 -15.2386389 4.6008989 6.5495511 3.9256743 6.5508348 6.6257171
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[799] [805] [811] [817] [829] [835] [841] [859] [859] [865] [871] [877] [887] [907] [913] [913] [925] [937] [943] [949] [955] [956] [967] [973] [979] [979] [987]	4.3326063 2.5670949 2.8383829 2.2123666 -1.5240476 -0.4637138 -7.0067177 -4.8625157 -7.3426184 -10.0867348 -14.0268289 4.9158326 4.9723153 4.6124522 5.8144205 7.2080876 6.5208818 5.6026105 4.5953362 5.7065900 4.4502785 1.6685070 2.0018403 0.6869066 -0.6233201 -4.3631575 -5.8013261 -8.9147194 -9.3477532 -12.0841674 -11.7127510 5.0322211 3.4404368 3.5551137 6.7690632	3.2808305 2.5606764 1.2632866 2.3694056 -1.6806586 -2.5681212 -6.7448435 -6.9686347 -7.5544284 -11.1385106 -14.8715016 -12.2343599 4.8597778 4.4982032 5.5084727 5.6060337 5.8922982 6.9419345 5.9188279 5.3860936 5.9706037 3.8726148 2.4130513 1.6342751 0.5786482 -1.4662812 -4.3674365 -5.0135641 -9.4444584 -10.8757806 -9.3468974 -13.7645268 4.5555416 5.7953063 4.6090290	5.1263589 1.8221227 1.4224650 0.2119387 -1.1522033 -3.3601623 -5.9053056 -8.0212662 -8.1877190 -11.9267006 -14.0811721 -12.3879757 4.2281989 4.6560979 5.6133080 5.5546858 6.1533166 7.7284128 5.9171163 5.6617547 4.9128373 4.9830128 2.1520329 1.9500645 -0.8937523 -1.8334186 -4.4791182 -5.0704746 -7.9720578 -10.9288400 -11.3464695 -15.2386389 4.6008989 4.5495511 3.9256743	4.4502785 1.6685070 2.0018403 0.6869066 -0.6233201 -4.3631575 -5.8013261 -8.9147194 -9.3477537 -11.7127510 5.0322211 3.4404368 3.55551137 6.7690632 4.8747543 4.8747543 4.8747543 2.5670949 2.8383829 2.2123666 -1.5240476 -0.4637138 -7.0067177 -4.8625157 -7.3426184 -10.0867348 -14.0268289 4.9158326 4.9723153 4.6124522	3.8726148 2.4130513 1.6342751 0.5786482 -1.4662812 -4.3674365 -5.0135641 -9.4444584 -10.8757806 -9.3468974 -13.7645268 4.5555416 5.7053063 4.6090290 5.5551137 6.46622597 5.3527175 5.5037659 4.9633294 6.9697479 3.280830 2.5696764 1.2632866 2.3694056 -1.6866586 -2.568121 -6.7448435 -6.9686347 -7.5544284 -11.1385106 -14.8715016 -12.2343599 4.8597778 4.4982032 5.5084727	4.9830128 2.1520329 1.9500645 -0.8937523 -1.8334186 -4.4791182 -5.0704746 -7.9720578 -10.9288400 -11.3464695 -15.2386389 4.6008989 6.5495511 3.9256743 6.55008348 6.6257171 5.6599490 5.0690205 5.9684642 5.1263589 1.8221227 1.4224650 0.2119387 -1.1522033 -3.3601623 -5.9953056 -8.0212662 -8.1877190 -11.9267006 -14.0811721 -12.3879757 4.2281989 4.6560079 5.6133080

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[1045]	2.5670949	2.5606764	1.8221227	1.6685070	2.4130513	2.1520329
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[1111]		4.8597778	4.2281989	3.4404368	5.7053063	6.5495511
[1117]	4.9723153	4.4982032	4.6560979	3.5551137	4.6090290	3.9256743
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[1129]		5.6060337	5.5546858	4.8747543	6.4622597	6.6257171
[1135]		5.8922982	6.1533166	4.8811728	5.3527175	5.2500217
[1141]	6.5208818	6.9419345	7.7284128	6.1443307	5.5037659	5.6599490
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[1153]		5.3860936	5.6017547	6.7596495	6.9697479	5.9684642
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[1225]	-11.7127510	-13.7645268	-15.2386389	-14.0268289	-12.2343599	-12.3879757
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[1243]	3.5551137	4.6090290	3.9256743	4.6124522	5.5084727	5.6133080
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[1345]	-14.2942658	-14.8715016	-14.0811721	-11.7127510	-13.7645268	-15.2386389
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[1357]		4.8597778	4.2281989		5.7053063	6.5495511
				3.4404368		
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[1369]	4.6124522	5.5084727	5.6133080	6.7690632	5.5551137	6.5508348
[1375]		5.6060337	5.5546858	4.8747543	6.4622597	6.6257171
[1381]		5.8922982	6.1533166	4.8811728	5.3527175	5.2500217
[1387]		6.9419345	7.7284128	6.1443307	5.5037659	5.6599490
[1393]		5.9188279	5.9171163	4.6509631	4.9633294	5.0690205
[1399]	4.5953362	5.3860936	5.6017547	6.7596495	6.9697479	5.9684642
[1405]	5.7065900	5.9706037	4.9128373	4.3326063	3.2808305	5.1263589
[1411]		3.8726148	4.9830128	2.5670949	2.5606764	1.8221227
		J.UUITO				1.4224650
[1417]		2 4120512	2 1520220		1 2622066	
		2.4130513	2.1520329	2.8383829	1.2632866	
[1423]		2.4130513 1.6342751	2.1520329 1.9500645		1.2632866 2.3694056	0.2119387
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[1429]	2.0018403 0.6869066	1.6342751 0.5786482	1.9500645 -0.8937523	2.8383829 2.2123666 -1.5240476	2.3694056 -1.6806586	0.2119387 -1.1522033
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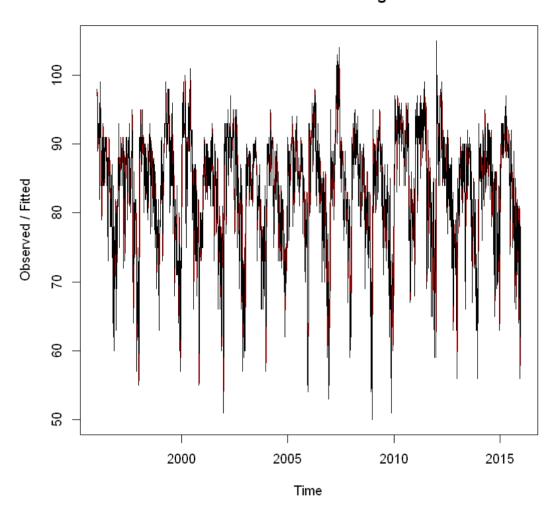
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```



Now, I am going to perform single exponential smoothing. Here, I'm using a model with no trend and seasonality. I am going to let R determine the value of alpha.

```
In [13]: temp_single_es <- HoltWinters(temp_ts, beta = FALSE, gamma = FALSE)
plot(temp_single_es)</pre>
```

Holt-Winters filtering



```
In [14]: temp_single_es
temp_single_es$SSE

Holt-Winters exponential smoothing without trend and without seasonal component.

Call:
    HoltWinters(x = temp_ts, beta = FALSE, gamma = FALSE)

Smoothing parameters:
    alpha: 0.8388021
    beta : FALSE
    gamma: FALSE
    gamma: FALSE

Coefficients:
        [,1]
    a 63.30952
```

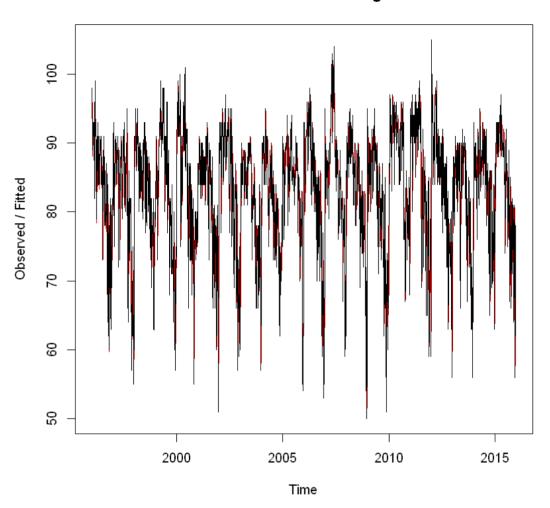
The estimated value of alpha is 0.8388021. This is high value indicating that the estimate of the current value of the levelis based mostly upon very recent observations in the time series. The value of the SSE for the in-sample forecast errors is 56198.0955314733.

I am going to perform double exponential smoothing (gamma = FALSE). I am going to let R determine the value of alpha.

56198.0955314733

```
In [15]: temp_double_es <- HoltWinters(temp_ts, gamma = FALSE)
plot(temp_double_es)</pre>
```

Holt-Winters filtering



```
In [16]: temp_double_es
temp_double_es$SSE

Holt-Winters exponential smoothing with trend and without seasonal component.

Call:
    HoltWinters(x = temp_ts, gamma = FALSE)

Smoothing parameters:
    alpha: 0.8445729
    beta: 0.003720884
    gamma: FALSE

Coefficients:
        [,1]
    a 63.2530022
    b -0.0729933
```

The estimated value of alpha is 0.8388021. Beta is 0.0037. This means that the trend value from the recent observations has relatively very little weight when forecasting for future values. The value of the sum-of-squared-errors for the in-sample forecast errors is 56572.537568114.

Next, I am going to check if the data can be described using an additive model. I am going to use Holt-Winters triple exponential smoothing to estimate the level (alpha), slope (beta) and seasonal (gamma) components.

56572.5375681139

```
In [17]: temp_add_hw <- HoltWinters(temp_ts)
temp_add_hw
temp_add_hw$SSE</pre>
```

Holt-Winters exponential smoothing with trend and additive seasonal component.

Call: HoltWinters(x = temp_ts) Smoothing parameters: alpha: 0.6610618 beta: 0 gamma: 0.6248076 Coefficients: [,1] 71.477236414 -0.004362918 b 18.590169842 s1 s2 17.803098732 s3 12.204442890 s4 13.233948865 s5 12.957258705 11.525341233 56 s7 10.854441534 s8 10.199632666 s9 8.694767348 5.983076192 s10 3.123493477 s11 4.698228193 s12 s13 2.730023168 s14 2.995935818 s15 1.714600919 2.486701224 s16 6.382595268 s17 s18 5.081837636 s19 7.571432660 s20 6.165047647 9.560458487 s21 9.700133847 s22 s23 8.808383245 s24 8.505505527 s25 7.406809208 s26 6.839204571 s27 6.368261304 6.382080380 s28 s29 4.552058253 s30 6.877476437 s31 4.823330209 s32 4.931885957 s33 7.109879628 6.178469084 s34 s35 4.886891317 s36 3.890547248 s37 2.148316257 2.524866001 s38 s39 3.008098232 s40 3.041663870 s41 2.251741386 s42 0.101091985 s43 -0.123337548 -1.445675315 s44 s45 -1.802768181 s46 -2.192036338 s47 -0.180954242 s48 1.538987281 5.075394760 s49 6.740978049 s50 s51 7.737089782 s52 8.579515859 8.408834158 s53 s54 4.704976718 s55 1.827215229 s56 -1.275747384 s57 1.389899699 s58 1.376842871 s59 0.509553410 560 1.886439429 -0.806454923 s61 s62 5.221873550 s63 5.383073482 s64 4.265584552 3.841481452 s65 566 -0.231239928 s67 0.542761270 s68 0.780131779 1.096690727 s69 0.690525998 s70

s71 s72 2.301303414

2.965913580

```
s73
       4.393732595
s74
       2.744547070
s75
       1.035278911
s76
       1.170709479
s77
       2.796838283
s78
       2.000312540
s79
       0.007337449
s80
      -1.203916069
s81
       0.352397232
       0.675108103
s82
s83
      -3.169643942
s84
      -1.913321175
s85
      -1.647780450
s86
      -5.281261301
s87
      -5.126493027
      -2.637666754
s88
s89
      -2.342133004
590
      -3.281910970
s91
      -4.242033198
s92
      -2.596010530
s93
      -7.821281290
s94
      -8.814741200
s95
      -8.996689798
s96
      -7.835655534
s97
      -5.749139155
s98
      -5.196182693
s99
      -8.623793296
s100 -11.809355220
s101 -13.129428554
s102 -16.095143067
s103 -15.125436350
s104 -13.963606549
s105 -12.953304848
s106 -16.097179844
s107 -15.489223470
s108 -13.680122300
s109 -11.921434142
s110 -12.035411347
s111 -12.837047727
s112 -9.095808127
s113 -5.433029341
s114 -6.800835107
s115 -8.413639598
s116 -10.912409484
s117 -13.553826535
s118 -10.652543677
s119 -12.627298331
s120 -9.906981556
s121 -12.668519900
s122 -9.805502547
s123 -7.775306633
```

66244.2504058464

The value of beta is zero, suggesting no trend from recent observations on forecasting future values. The level parameter is 0.6610618, and the seasonal smoothing parameter, gamma is 0.6248076. SSE is 66244.2504058466.

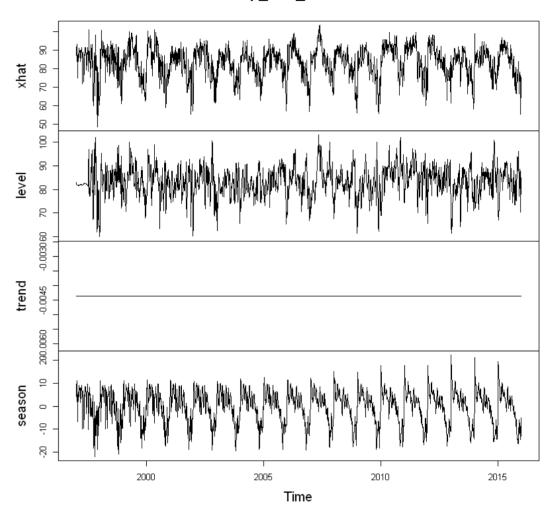
The forecasts made by HoltWinters function are stored in a named element of this list variable called fitted.

In [18]: temp_add_hw\$fitted
plot(temp_add_hw\$fitted)

xhat	level	trend	season
87.17619	82.87739	-0.004362918	4.303159
90.32925	82.09550	-0.004362918	8.238119
92.96089	81.87348	-0.004362918	11.091777
90.93360	81.89497	-0.004362918	9.042997
83.99752	81.93450	-0.004362918	2.067387
84.04358	81.93177	-0.004362918	2.116168
75.06732	81.89860	-0.004362918	-6.826922
87.04284	81.84974	-0.004362918	5.197468
84.01829	81.81705	-0.004362918	2.205599
87.05875	81.80060	-0.004362918	5.262509
84.04807	81.75740	-0.004362918	2.295029
88.04445	81.72126	-0.004362918	6.327550
86.02696	81.68752	-0.004362918	4.343810
89.93161	81.66533	-0.004362918	8.270639
90.90741	81.70618	-0.004362918	9.205599
90.94800	81.76302	-0.004362918	9.189338
88.92923	81.79304	-0.004362918	7.140558
88.90661	81.83546	-0.004362918	7.075517
88.88268	81.89283	-0.004362918	6.994216
89.85831	81.96602	-0.004362918	7.896655
88.81753	82.05532	-0.004362918	6.766574
83.84436	82.17158	-0.004362918	1.677143
87.03232	82.27010	-0.004362918	4.766574
88.03911	82.24438	-0.004362918	5.799094
89.02515	82.21416	-0.004362918	6.815355
89.17489	82.19317	-0.004362918	6.986086
91.16874	82.07319	-0.004362918	9.099907
91.17478	81.95728	-0.004362918	9.221859
89.11179	81.83738	-0.004362918	7.278769
87.99288	81.75912	-0.004362918	6.238119
72.64256	 80.05496	-0.004362918	-7.408039
66.83529	75.65946	-0.004362918	-8.819799
66.52752	75.10291	-0.004362918	-8.571026
71.27533		-0.004362918	
72.61174		-0.004362918	
	80.76531	-0.004362918	
		-0.004362918	
79.43815	92.90270	-0.004362918	
79.66666	93.93081	-0.004362918	
73.08558	88.19726	-0.004362918	
73.67625	88.13632	-0.004362918	
75.55797	89.66810	-0.004362918	
76.93396		-0.004362918	
77.78777		-0.004362918	
83.84604	96.08073		
82.21082	91.55071	-0.004362918	
72.89454	83.47425	-0.004362918	-10.575347
66.62710	78.91217	-0.004362918	-12.280703
67.28402	77.17113	-0.004362918	
73.69847	79.62326	-0.004362918	
73.08186		-0.004362918	
75.45623	85.04824	-0.004362918	
78.27330	88.70865	-0.004362918	
74.35348		-0.004362918	
55540	320100	3.00.002010	.2.0 10000

xhat	level	trend	season
76.29092	84.98028	-0.004362918	-8.684994
68.94343	78.83404	-0.004362918	-9.886253
55.62316	70.27328	-0.004362918	-14.645752
73.03021	85.06139	-0.004362918	-12.026808
74.11555	83.05386	-0.004362918	-8.933947
75.38342	80.32887	-0.004362918	-4.941084

temp_add_hw\$fitted



I am going to check if the data can be described using an multiplicative model. I am going to use Holt-Winters triple exponential smoothing to estimate the level (alpha), slope (beta) and seasonal (gamma) components.

```
In [19]: temp_mul_hw <- HoltWinters(temp_ts, seasonal = "multiplicative")
temp_mul_hw
temp_mul_hw$SSE</pre>
```

Holt-Winters exponential smoothing with trend and multiplicative seasonal component.

Call: HoltWinters(x = temp_ts, seasonal = "multiplicative") Smoothing parameters: alpha: 0.615003 beta: 0 gamma: 0.5495256 Coefficients: [,1] 73.679517064 -0.004362918 b 1.239022317 s1 s2 1.234344062 s3 1.159509551 s4 1.175247483 s5 1.171344196 s6 1.151038408 s7 1.139383104 s8 1.130484528 s9 1.110487514 s10 1.076242879 1.041044609 s11 1.058139281 s12 s13 1.032496529 s14 1.036257448 s15 1.019348815 s16 1.026754142 1.071170378 s17 s18 1.054819556 s19 1.084397734 s20 1.064605879 1.109827336 s21 1.112670130 s22 1.103970506 s23 s24 1.102771209 s25 1.091264692 s26 1.084518342 s27 1.077914660 1.077696145 s28 1.053788854 s29 s30 1.079454300 s31 1.053481186 s32 1.054023885 1.078221405 s33 1.070145761 s34 s35 1.054891375 s36 1.044587771 s37 1.023285461 1.025836722 s38 s39 1.031075732 s40 1.031419152 s41 1.021827552 s42 0.998177248 s43 0.996049257 s44 0.981570825 s45 0.976510542 s46 0.967977608 s47 0.985788411 s48 1.004748195 1.050965934 s49 s50 1.072515008 s51 1.086532279 s52 1.098357400 1.097158461 s53 1.054827180 s54 s55 1.022866587 s56 0.987259326 s57 1.016923524 s58 1.016604903 s59 1.004320951 560 1.019102781 0.983848662 s61 s62 1.055888360 s63 1.056122844 s64 1.043478958 1.039475693 s65 566 0.991019224 s67 1.001437488 s68 1.002221759 s69 1.003949213 s70 0.999566344

s71 s72 1.018636837

1.026490773

```
s73
      1.042507768
s74
      1.022500795
s75
      1.002503740
s76
      1.004560984
s77
      1.025536556
s78
      1.015357769
s79
      0.992176558
s80
      0.979377825
s81
      0.998058079
s82
      1.002553395
583
      0.955429116
s84
      0.970970220
s85
      0.975543504
s86
      0.931515830
s87
      0.926764603
s88
      0.958565273
s89
      0.963250387
590
      0.951644060
s91
      0.937362688
s92
      0.954257999
s93
      0.892485444
s94
      0.879537700
s95
      0.879946892
s96
      0.890633648
s97
      0.917134959
s98
      0.925991769
      0.884247686
599
s100
      0.846648167
s101
      0.833696369
      0.800001437
s103
      0.807934782
s104
      0.819343668
      0.828571029
s105
s106
      0.795608740
s107
      0.796609993
s108
      0.815503509
s109
      0.830111282
5110
      0.829086181
s111
      0.818367239
s112
      0.863958784
s113
      0.912057203
s114
      0.898308248
s115
      0.878723779
s116
      0 848971946
s117
      0.813891909
s118
      0.846821392
s119
      0.819121827
s120
      0.851036184
      0.820416491
s121
s122
      0.851581233
s123
     0.874038407
```

68904.5693317479

Again, the value of beta is zero, suggesting no trend from recent observations on forecasting future values. The level parameter is 0.615003, and the seasonal smoothing parameter, gamma is 0.5495256. SSE is 68904.5693317479.

I am going to write the fitted values to a csv file to perform CUSUM approach to detect unofficial end of summer.

```
In [20]: df_temp1 <- matrix(temp_mul_hw$fitted[,4], nrow = 123)
In [27]: write.csv(df_temp1, file = 'smoothed_temperature.csv')</pre>
```

Next, I am going to try to predict the temperatures for July 1 through Oct 31 for 2016 and 2017 using the Holt-Winters mulultiplicative model. To do this, I am using the predict() function that inputs the HW object, prediction interval, number of predictions, and confidence level.

In [29]: head(temperature_data)

	DAY	X1996	X1997	X1998	X1999	X2000	X2001	X2002	X2003	X2004	 X2008	X2009	X2010	X2011	X2012	X2013	X2014	X2015	X2016	X2017
V1	1- Jul	98	86	91	84	89	84	90	73	82	 85	95	87	92	105	82	90	85	91	91
V2	2- Jul	97	90	88	82	91	87	90	81	81	 87	90	84	94	93	85	93	87	91	90
V3	3- Jul	97	93	91	87	93	87	87	87	86	 91	89	83	95	99	76	87	79	85	85
V4	4- Jul	90	91	91	88	95	84	89	86	88	 90	91	85	92	98	77	84	85	87	86
V5	5- Jul	89	84	91	90	96	86	93	80	90	 88	80	88	90	100	83	86	84	86	86
V6	6- Jul	93	84	89	91	96	87	93	84	90	 82	87	89	90	98	83	87	84	85	84

In this problem, I have used Holt Winters approach to exponentially smoothe data, and use the smoothed data to predict unofficial end of summer using CUSUM approach. In addition, I have also used the smoothed data to predict temperatures of each day (July1 to Oct 31) for the next two years.

In []: