HW3, Ashish EDA

```
library(grid)


data = read.table('../temps.txt', sep="\t", dec=".", header = TRUE)
data
```

```
##        DAY X1996 X1997 X1998 X1999 X2000 X2001 X2002 X2003 X2004 X2005 X2006
## 1    1-Jul    98    86    91    84    89    84    90    73    82    91    93
## 2    2-Jul    97    90    88    82    91    87    90    81    81    89    93
## 3    3-Jul    97    93    91    87    93    87    87    87    86    86    93
## 4    4-Jul    90    91    91    88    95    84    89    86    88    86    91
## 5    5-Jul    89    84    91    90    96    86    93    80    90    89    90
## 6    6-Jul    93    84    89    91    96    87    93    84    90    82    81
## 7    7-Jul    93    75    93    82    96    87    89    87    89    76    80
## 8    8-Jul    91    87    95    86    91    89    89    90    87    88    82
## 9    9-Jul    93    84    95    87    96    91    90    89    88    89    84
## 10  10-Jul    93    87    91    87    99    87    91    84    89    78    84
## 11  11-Jul    90    84    91    82    96    90    84    84    90    83    90
## 12  12-Jul    91    88    86    77    93    90    77    86    89    86    91
## 13  13-Jul    93    86    88    73    91    86    82    87    91    84    91
## 14  14-Jul    93    90    87    81    93    82    88    84    91    87    91
## 15  15-Jul    82    91    91    81    93    82    91    86    84    84    91
## 16  16-Jul    91    91    87    86    93    84    93    88    84    85    91
## 17  17-Jul    96    89    90    82    91    87    93    88    84    89    93
## 18  18-Jul    95    89    91    87    97    88    93    88    87    90    93
## 19  19-Jul    96    89    95    88   100    90    93    88    84    89    96
## 20  20-Jul    99    90    91    90    99    87    91    88    88    89    93
## 21  21-Jul    91    89    91    90    93    84    95    89    89    90    93
## 22  22-Jul    95    84    89    91    96    87    91    86    89    91    91
## 23  23-Jul    91    87    91    93    87    90    89    81    93    91    86
## 24  24-Jul    93    88    91    93    82    84    87    82    95    90    87
## 25  25-Jul    84    89    86    91    75    82    84    84    89    92    88
## 26  26-Jul    84    89    88    93    82    88    86    87    87    94    93
## 27  27-Jul    82    91    80    93    88    90    89    87    84    92    95
## 28  28-Jul    79    91    88    93    91    84    91    89    89    90    96
## 29  29-Jul    90    89    89    93    89    89    91    88    87    83    91
## 30  30-Jul    91    88    90    97    87    89    88    84    89    78    91
## 31  31-Jul    87    72    86    99    86    87    90    88    90    84    94
## 32   1-Aug    86    80    86    96    86    84    93    84    91    82    95
## 33   2-Aug    90    84    82    93    81    84    91    84    90    86    95
## 34   3-Aug    84    88    84    88    84    84    91    84    91    88    97
## 35   4-Aug    91    89    86    89    88    86    91    82    91    91    98
## 36   5-Aug    93    88    90    91    91    88    93    84    90    88    96
## 37   6-Aug    88    84    89    93    91    84    97    82    84    86    89
## 38   7-Aug    91    84    89    93    91    86    87    84    81    80    97
## 39   8-Aug    84    80    86    93    91    88    87    84    82    82    96
```

```
## 40   9-Aug    90    73    82    91    96    87    86    86    84    85    95
## 41  10-Aug    89    80    87    90    95    88    88    87    75    83    96
## 42  11-Aug    88    86    88    96    89    86    89    84    82    87    88
## 43  12-Aug    86    88    84    98    89    86    91    81    80    88    84
## 44  13-Aug    84    88    86    97    89    81    91    87    77    86    81
## 45  14-Aug    86    87    80    98    89    87    89    89    82    90    87
## 46  15-Aug    89    88    82    93    94    84    88    90    82    92    86
## 47  16-Aug    90    91    86    93    97    90    90    86    84    89    89
## 48  17-Aug    91    91    84    96    99    91    91    89    86    90    86
## 49  18-Aug    91    89    87    98   101    91    93    90    86    90    88
## 50  19-Aug    90    89    90    98   101    87    91    90    89    89    88
## 51  20-Aug    89    88    79    89    97    86    93    87    88    92    93
## 52  21-Aug    90    82    84    91    87    88    93    88    82    94    91
## 53  22-Aug    91    79    87    91    86    90    91    88    84    93    88
## 54  23-Aug    91    81    87    90    88    88    95    90    84    87    87
## 55  24-Aug    91    82    88    80    92    93    93    89    87    85    83
## 56  25-Aug    84    84    90    82    92    90    91    88    82    84    85
## 57  26-Aug    88    87    91    89    90    91    88    89    86    84    88
## 58  27-Aug    84    90    89    88    90    91    84    90    88    86    88
## 59  28-Aug    86    90    90    90    92    81    82    91    90    86    90
## 60  29-Aug    88    91    93    91    92    86    82    89    87    85    90
## 61  30-Aug    84    91    93    91    88    81    78    88    88    85    88
## 62  31-Aug    82    88    91    84    87    82    77    89    87    85    80
## 63   1-Sep    80    88    87    88    79    80    84    88    82    85    85
## 64   2-Sep    73    91    84    91    81    75    84    86    80    88    86
## 65   3-Sep    87    93    77    84    82    73    89    87    81    87    85
## 66   4-Sep    84    81    90    93    87    81    95    87    82    85    88
## 67   5-Sep    87    81    91    96    81    90    93    84    84    81    83
## 68   6-Sep    89    82    89    96    66    88    91    73    81    81    85
## 69   7-Sep    89    86    90    91    66    87    88    75    86    83    80
## 70   8-Sep    89    88    89    91    75    86    87    81    73    85    83
## 71   9-Sep    91    84    79    77    80    86    91    82    84    86    83
## 72  10-Sep    84    80    78    87    82    89    95    79    84    84    85
## 73  11-Sep    86    82    81    87    84    87    95    80    84    84    84
## 74  12-Sep    88    86    84    87    86    84    90    81    81    86    82
## 75  13-Sep    78    87    89    86    87    84    75    84    79    88    70
## 76  14-Sep    79    87    87    87    86    86    78    82    79    88    80
## 77  15-Sep    86    88    87    89    80    77    91    82    73    91    82
## 78  16-Sep    82    88    88    81    75    77    88    81    75    88    83
## 79  17-Sep    82    90    87    81    73    81    86    81    80    86    85
## 80  18-Sep    78    88    82    82    73    81    81    81    79    88    85
## 81  19-Sep    79    91    80    79    84    82    80    84    78    90    79
## 82  20-Sep    79    95    82    68    87    84    86    87    73    90    73
## 83  21-Sep    78    89    82    79    77    86    84    82    75    90    75
## 84  22-Sep    81    70    88    72    73    87    77    75    80    86    82
## 85  23-Sep    84    80    84    75    81    88    82    81    84    87    86
## 86  24-Sep    84    82    81    78    84    69    73    80    82    88    84
## 87  25-Sep    87    66    82    81    82    66    69    82    81    85    75
## 88  26-Sep    84    70    84    82    68    72    75    82    79    77    78
## 89  27-Sep    79    64    87    78    71    75    75    82    72    86    79
## 90  28-Sep    75    68    80    80    75    78    79    73    78    85    81
## 91  29-Sep    72    77    75    77    73    71    73    66    78    85    70
## 92  30-Sep    64    86    75    71    75    71    79    71    80    82    75
## 93   1-Oct    66    75    86    73    77    75    82    72    82    83    83
```

```
## 94   2-Oct    72    73    78    75    79    80    84    68    82    85    81
## 95   3-Oct    84    75    77    84    82    81    84    66    80    83    82
## 96   4-Oct    70    78    82    71    81    80    82    77    81    85    84
## 97   5-Oct    66    81    82    73    82    79    87    78    80    81    86
## 98   6-Oct    64    82    73    71    73    70    86    75    75    72    76
## 99   7-Oct    60    82    82    73    66    68    80    73    75    72    72
## 100  8-Oct    78    82    69    73    55    79    71    73    73    73    72
## 101  9-Oct    70    80    72    72    55    66    66    73    71    70    79
## 102 10-Oct    72    82    73    72    64    73    70    73    71    77    80
## 103 11-Oct    69    82    78    73    71    75    78    66    77    82    80
## 104 12-Oct    69    79    78    70    73    78    84    78    73    74    71
## 105 13-Oct    73    80    78    64    75    78    79    78    64    77    62
## 106 14-Oct    79    68    75    75    75    75    68    78    63    78    69
## 107 15-Oct    81    63    79    73    77    75    57    69    62    79    70
## 108 16-Oct    80    57    78    77    80    62    66    72    71    76    59
## 109 17-Oct    82    66    77    80    80    60    64    68    75    75    71
## 110 18-Oct    66    64    78    71    80    64    68    70    73    81    77
## 111 19-Oct    63    69    82    66    73    71    71    75    68    83    76
## 112 20-Oct    68    70    75    60    73    75    73    78    71    83    69
## 113 21-Oct    79    70    73    64    75    79    71    84    73    80    69
## 114 22-Oct    81    62    63    73    79    80    64    78    73    67    70
## 115 23-Oct    69    63    63    57    75    81    59    78    70    70    53
## 116 24-Oct    73    62    72    59    75    79    68    73    73    56    56
## 117 25-Oct    73    75    75    64    78    73    60    73    78    54    55
## 118 26-Oct    75    71    79    69    75    64    68    68    79    61    62
## 119 27-Oct    75    57    79    75    78    51    69    64    81    63    66
## 120 28-Oct    81    55    79    73    80    55    75    57    78    62    63
## 121 29-Oct    82    64    78    72    75    63    75    70    75    64    72
## 122 30-Oct    82    66    82    75    77    72    68    77    78    69    73
## 123 31-Oct    81    60    79    75    78    71    60    75    82    70    68
##     X2007 X2008 X2009 X2010 X2011 X2012 X2013 X2014 X2015
## 1      95    85    95    87    92   105    82    90    85
## 2      85    87    90    84    94    93    85    93    87
## 3      82    91    89    83    95    99    76    87    79
## 4      86    90    91    85    92    98    77    84    85
## 5      88    88    80    88    90   100    83    86    84
## 6      87    82    87    89    90    98    83    87    84
## 7      82    88    86    94    94    93    79    89    90
## 8      82    90    82    97    94    95    88    90    90
## 9      89    89    84    96    91    97    88    90    91
## 10     86    87    84    90    92    95    87    87    93
## 11     85    89    86    93    95    90    80    85    92
## 12     87    93    90    90    95    84    87    90    93
## 13     86    85    84    91    97    90    78    89    92
## 14     84    88    89    91    90    90    85    90    90
## 15     81    89    89    94    80    90    86    86    89
## 16     86    89    90    89    85    92    87    83    88
## 17     89    88    88    87    87    93    91    86    93
## 18     89    90    82    83    89    93    87    82    92
## 19     88    91    80    90    94    91    90    85    91
## 20     86    94    82    91    91    84    86    76    93
## 21     86    95    86    94    92    90    87    82    93
## 22     79    92    84    95    94    95    85    83    92
## 23     82    87    87    97    92    97    84    88    88
```

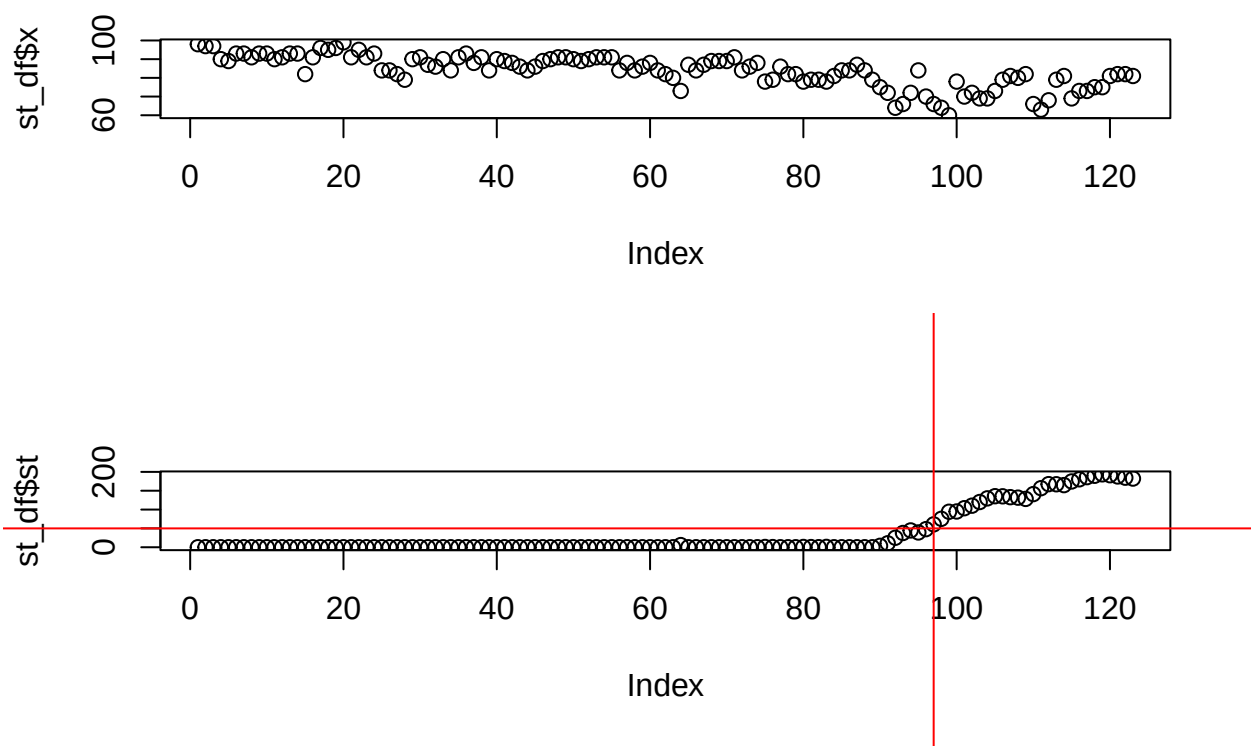
```
## 24   87   88   88   94   92   97   86   87   91
## 25   87   89   90   95   90   98   89   88   90
## 26   87   87   92   95   94   98   86   89   91
## 27   90   90   90   93   94   97   82   92   92
## 28   89   93   89   90   90   97   86   90   94
## 29   87   92   85   94   93   94   86   82   93
## 30   92   90   82   95   96   96   90   84   94
## 31   90   88   85   95   96   88   80   85   93
## 32   92   89   89   96   91   94   87   81   89
## 33   92   92   83   84   96   99   89   84   94
## 34   94   91   90   92   97   94   88   88   94
## 35   97   91   92   95   85   87   90   90   97
## 36   96   92   92   93   96   90   88   89   95
## 37   98   94   89   93   93   86   88   92   88
## 38   98   90   91   91   93   84   86   95   88
## 39  100   86   92   93   94   92   83   90   92
## 40  103   85   93   94   91   88   89   89   93
## 41  103   85   93   94   95   87   90   86   94
## 42  100   88   95   95   94   85   90   83   91
## 43   90   81   86   95   95   88   90   88   90
## 44  100   81   90   96   95   91   89   84   89
## 45   99   84   90   89   94   88   83   85   90
## 46  102   87   90   90   88   85   73   87   90
## 47  101   86   88   90   90   91   67   88   90
## 48  101   85   87   91   92   87   66   89   89
## 49   97   86   88   93   94   87   77   89   88
## 50   95   90   90   92   96   84   82   86   89
## 51   96   90   88   93   93   84   84   89   88
## 52   99   85   88   93   94   88   84   92   89
## 53  104   82   85   94   98   84   88   93   92
## 54   98   78   81   93   92   88   90   93   87
## 55   95   83   86   90   93   86   84   88   89
## 56   94   78   87   89   95   85   82   84   84
## 57   92   83   90   90   99   90   82   86   86
## 58   88   80   83   89   95   90   86   88   85
## 59   88   86   75   87   95   80   90   91   83
## 60   89   89   86   84   93   86   92   92   81
## 61   89   89   79   85   90   80   87   88   74
## 62   86   88   79   89   92   89   90   89   84
## 63   84   81   71   90   95   91   90   90   87
## 64   83   85   78   91   96   89   84   90   90
## 65   88   83   79   92   95   85   90   92   89
## 66   91   85   83   84   80   77   89   82   92
## 67   89   88   83   85   78   85   89   89   87
## 68   85   87   85   90   75   85   88   91   85
## 69   86   89   84   91   69   92   88   90   85
## 70   88   90   87   93   73   88   91   84   84
## 71   89   88   84   92   81   83   90   84   87
## 72   89   87   80   94   84   84   89   86   85
## 73   89   83   75   96   86   83   89   90   86
## 74   86   87   81   89   87   81   90   92   78
## 75   85   86   80   86   89   81   87   86   75
## 76   81   88   82   91   92   83   82   78   77
## 77   82   79   79   91   86   87   84   80   80
```

```
## 78     76    80    82    89    72    86    89    86    79
## 79     78    69    73    95    79    83    79    86    83
## 80     79    82    80    93    77    79    78    85    83
## 81     82    81    74    92    77    81    84    84    87
## 82     81    79    81    96    82    79    86    83    89
## 83     78    75    79    95    86    85    73    87    77
## 84     86    84    84    92    80    87    82    82    76
## 85     83    82    83    91    83    81    82    77    81
## 86     89    78    85    88    82    78    71    78    74
## 87     87    82    87    93    88    82    67    77    67
## 88     84    80    85    76    86    86    78    74    71
## 89     85    77    80    81    84    88    79    78    71
## 90     85    86    83    76    79    86    77    74    75
## 91     81    86    72    79    84    84    76    71    77
## 92     79    86    74    76    78    72    77    84    85
## 93     80    74    76    79    65    75    82    86    71
## 94     82    74    75    78    68    72    82    85    66
## 95     77    80    76    68    75    74    82    78    66
## 96     80    83    74    67    80    82    85    65    70
## 97     81    83    62    70    83    82    84    71    73
## 98     82    82    71    73    81    83    84    78    76
## 99     83    82    79    81    79    68    74    82    81
## 100    83    72    80    82    78    63    72    86    82
## 101    81    75    85    85    72    70    76    86    81
## 102    81    77    74    86    68    73    80    86    71
## 103    67    78    77    86    65    75    79    86    73
## 104    72    77    66    80    73    79    81    85    76
## 105    74    77    73    80    74    75    82    85    81
## 106    78    80    66    73    77    77    77    75    78
## 107    78    81    61    78    80    77    68    69    81
## 108    76    83    61    76    84    74    74    70    77
## 109    82    69    51    80    85    75    72    80    70
## 110    77    67    55    78    80    74    73    76    66
## 111    76    65    61    82    67    73    63    73    64
## 112    75    66    68    77    59    71    70    73    71
## 113    78    72    71    80    63    76    72    77    76
## 114    72    68    74    78    68    79    69    70    79
## 115    81    62    72    76    70    78    63    72    81
## 116    59    54    69    81    73    79    66    74    76
## 117    61    67    65    76    76    80    56    77    71
## 118    68    70    65    85    77    80    61    84    67
## 119    67    59    60    76    79    70    69    84    56
## 120    70    50    71    74    74    56    64    77    78
## 121    62    59    75    68    59    56    75    73    70
## 122    67    65    66    71    61    56    78    68    70
## 123    71    67    69    75    65    65    74    63    62
```

```r
CUSUM_ad = function(x, year, days = data$DAY ,C = 0.30,T = 4, if_c_relative = FALSE){
  mean_x = mean(x)
  sd_x = sd(x)
  if (if_c_relative) {
    C = C * sd_x
  }
  #apply cusum
```

```
  x1 = lapply(x, function(xi)  (mean_x - xi - C))
  st_df = data.frame(st=double())
  st = 0
  for(i in 1:length(x)){
    #print (paste(i,class(st),class(x1[[i]])))
    st = max(0, st + x1[[i]])
    st_df[i,] = c(st)
  }
  #Find index where St > T
  st_df$Day = days
  st_df["anamoly"] = 0
  st_df$anamoly[st_df$st > T] = 1
  st_df$xt = x
  #plot x with T and if decrease see
  par(mfrow=c(2,1))
  plot(st_df$x)
  title(paste("Temperature (in Celsius) and S_t (bottom) for year",year), line = -1, outer = TRUE)
  plot(st_df$st)
  pushViewport(viewport())
  grid.lines(x = c(0,1), y = grconvertY(T, "user", "ndc"), gp = gpar(col = "red"))
  change_detected = which.max(st_df$st>T)
  grid.lines(x = grconvertX(change_detected, "user", "ndc"), y = c(0,1), gp = gpar(col = "red"))
  popViewport()
  #return first point where St touches T
  n_days_change_detected = length(which(st_df$st>T))
  return (c(as.numeric(year),as.numeric(change_detected),as.numeric(n_days_change_detected)))
}
```

```
CUSUM_ad(data$X1996,"1996", C= 5, T = 50)
```

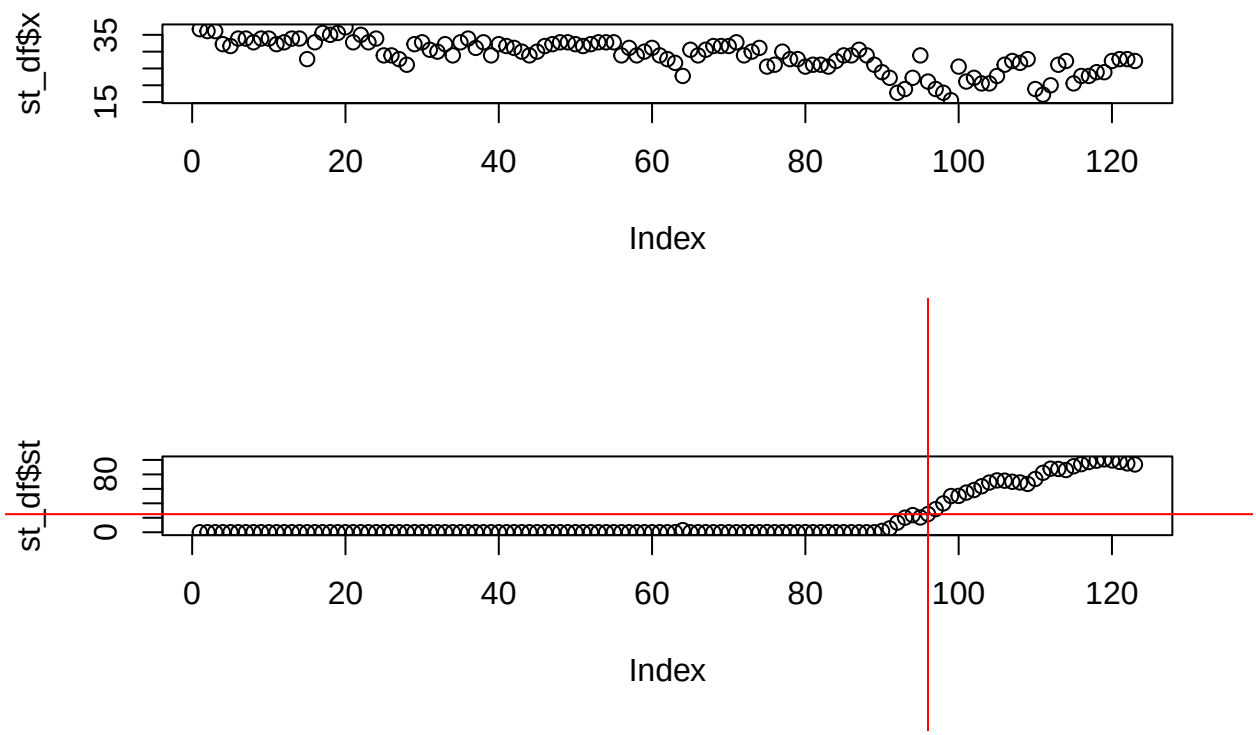



```
## [1] 1996   97   27
```

```
#library(ggplot2)
#par(mfrow=c(2,1))
#plot(check$x)
#plot(check$st)
#ggplot(check, aes(x = Day, y = st)) + geom_point() + geom_line() +
#  theme(axis.text.x = element_text(angle = 90))
```

```
### Transform to celsius
temp_cols = names(data)[!(names(data) %in% c("DAY"))]
#Transform to celsius
data_celsius = data
data_celsius[temp_cols] <- lapply(data_celsius[temp_cols], function(f) (f-32)*5/9)
```

```
CUSUM_ad(data_celsius[,"X1996"],1996, C = 3, T = 25)
```

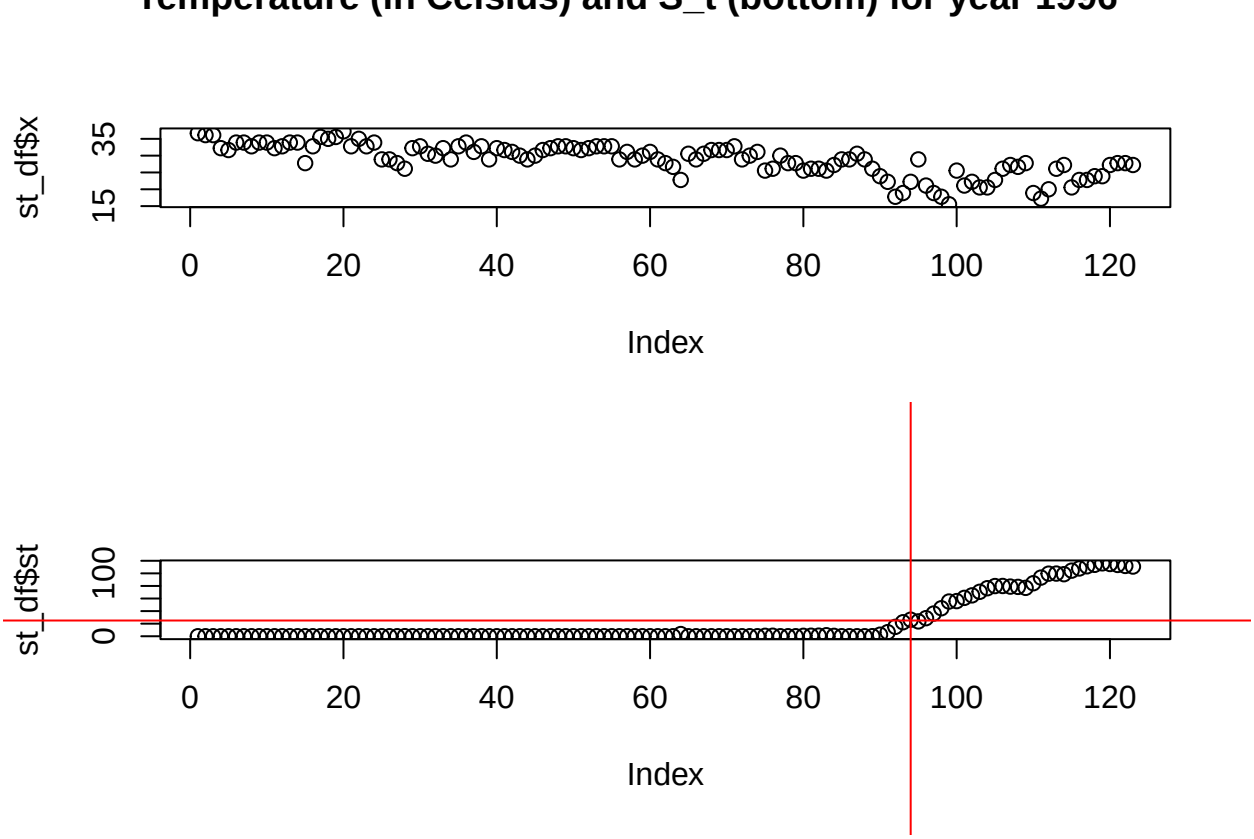



```
## [1] 1996   96   28
```

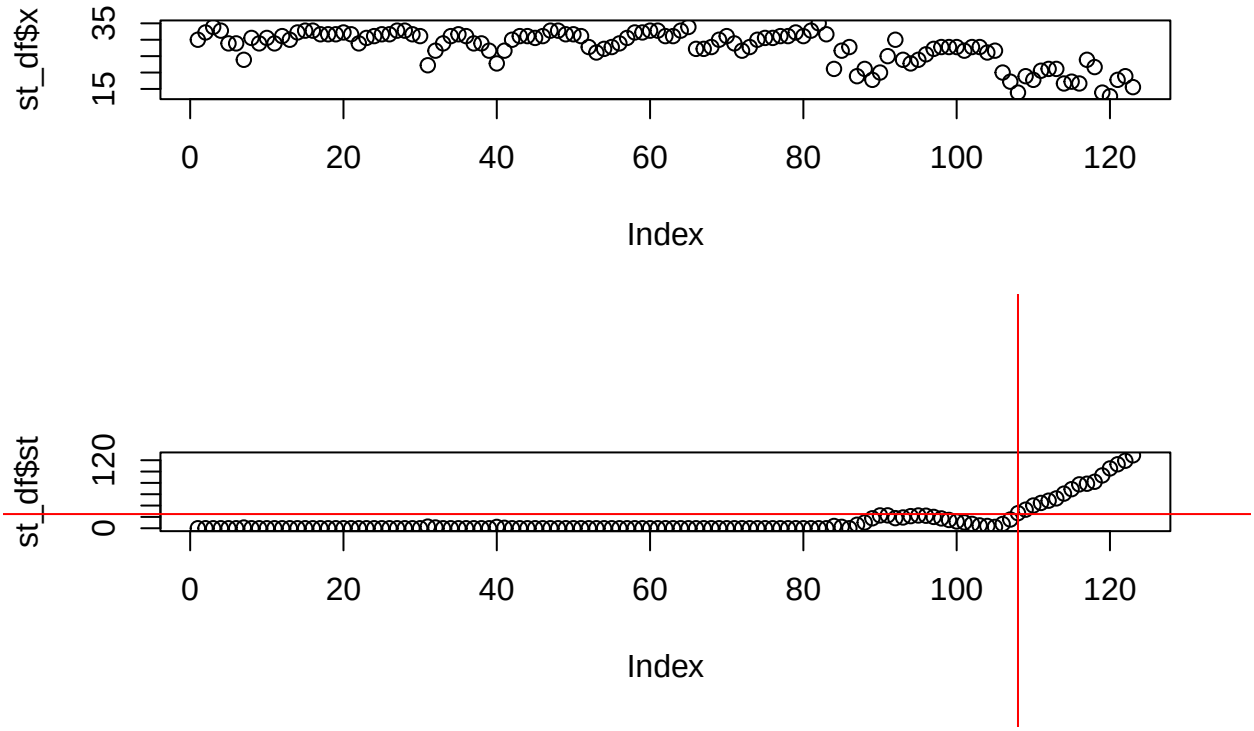
```
### Run Cusum over data_celsius for all the years
mean(unlist(lapply(temp_cols, function(col)
  sd(data_celsius[,col])
  )))
```

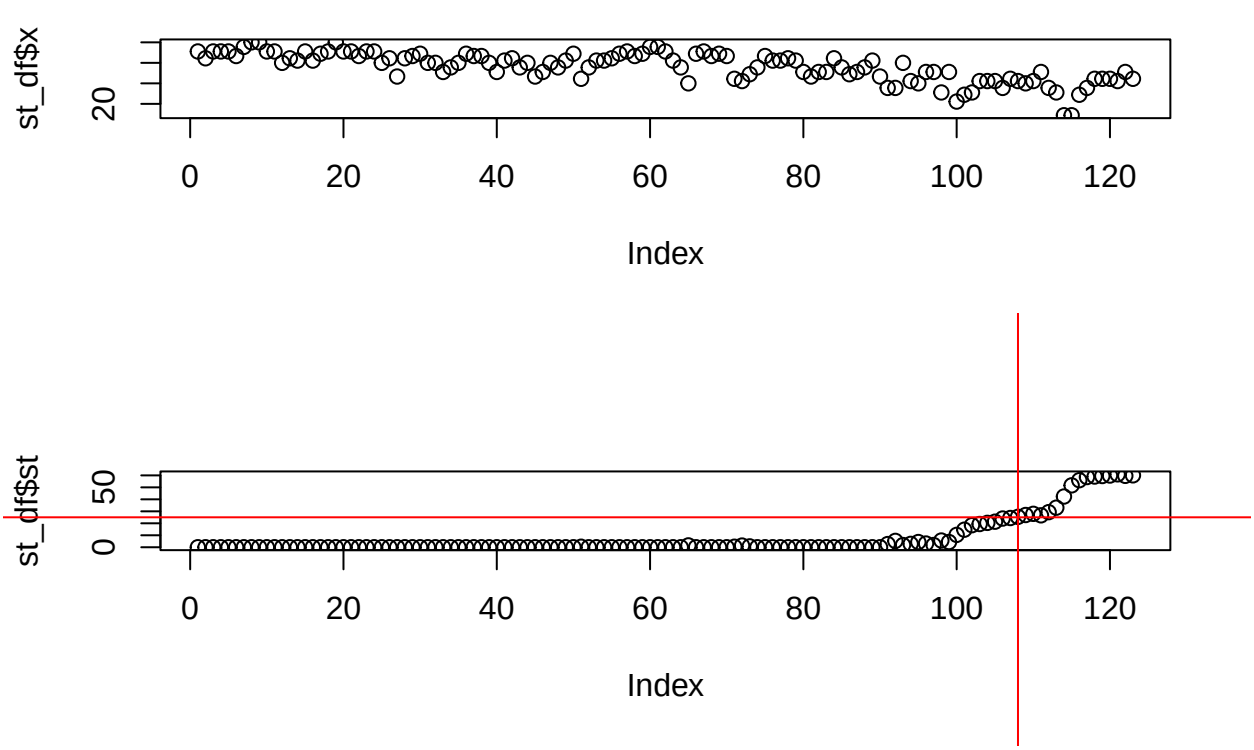
```
## [1] 4.689249
```

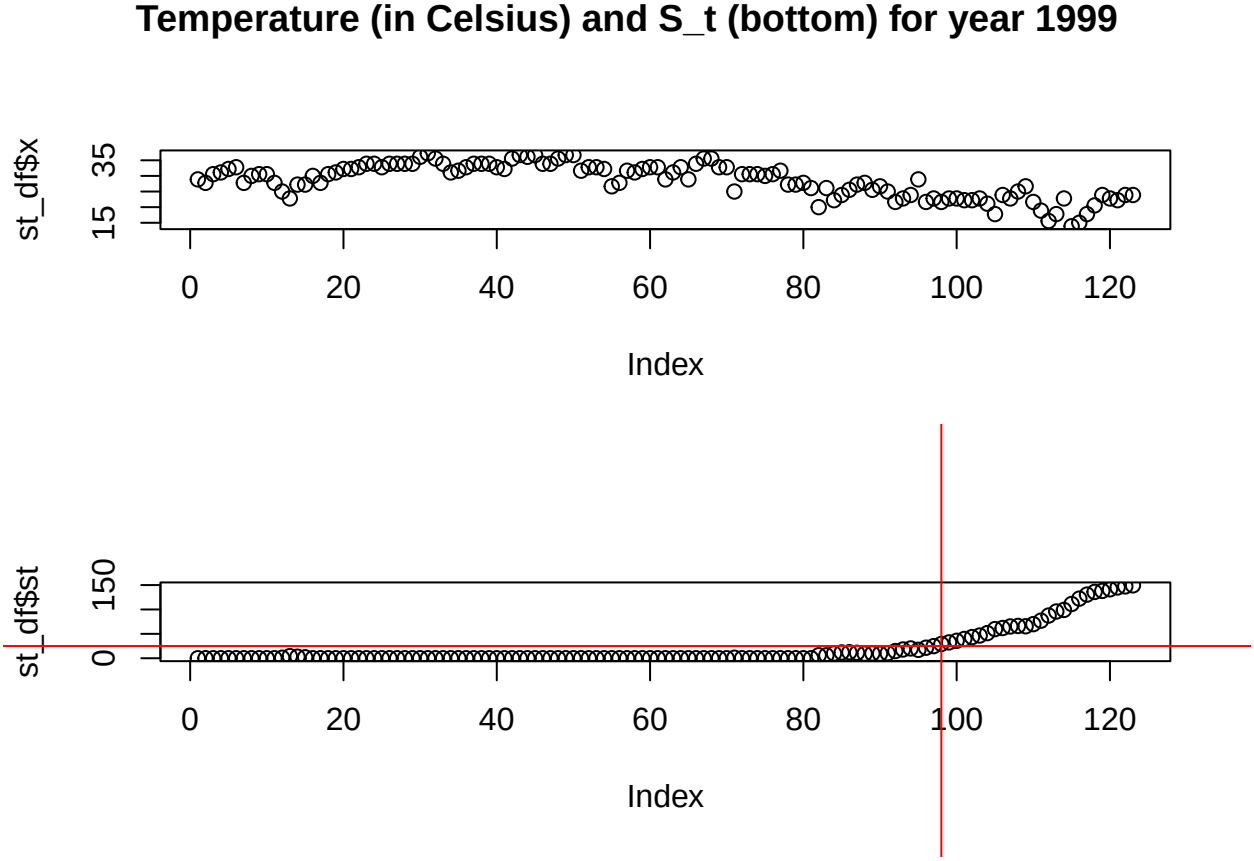
```
### Run Cusum over data_celsius for all the years
winter_start_days = lapply(temp_cols, function(col)
  CUSUM_ad(x=data_celsius[,col], year = substr(col,2,5), C = 2.5, T = 25)
  )
```

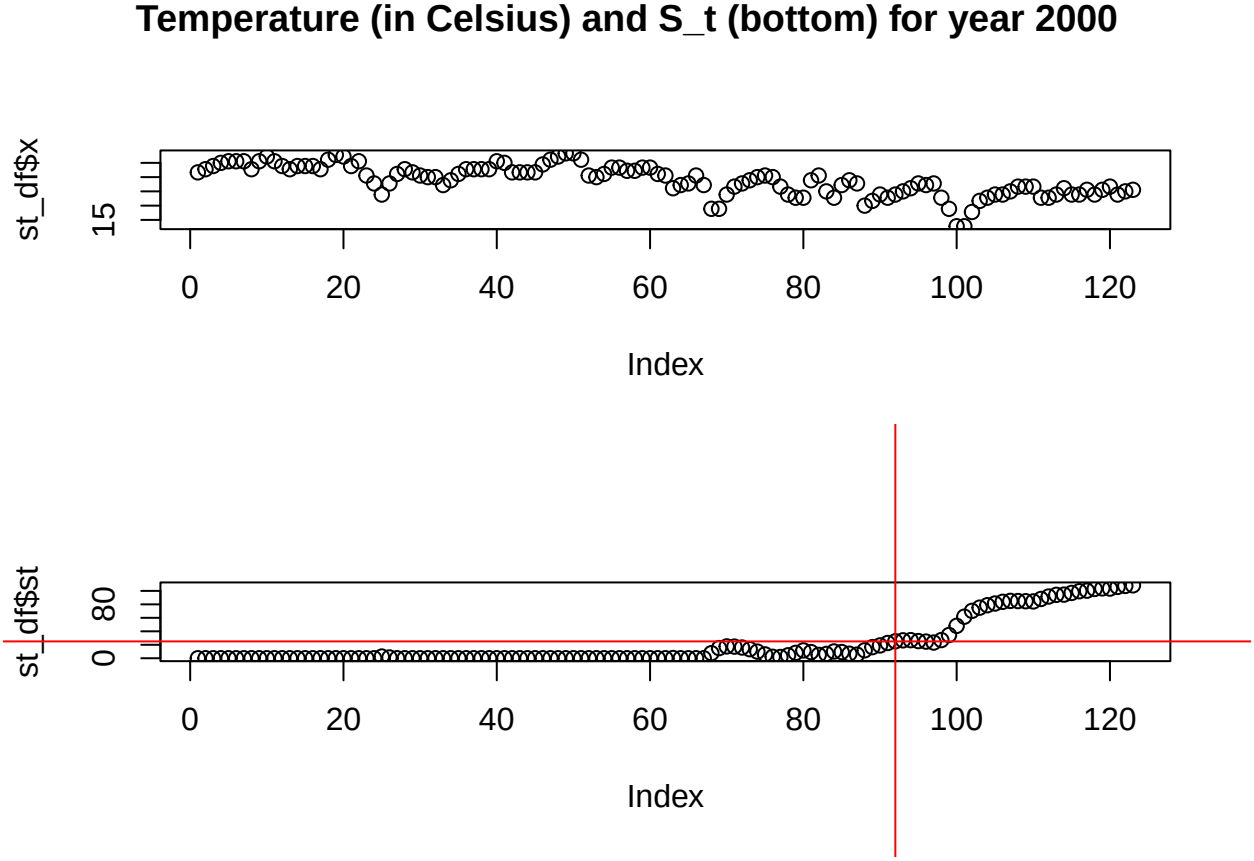

Temperature (in Celsius) and S_t (bottom) for year 1996
st_df$x
15
35
0
20
40
60
80
100
120
Index
st_df$st
0
100
0
20
40
60
80
100
120
Index

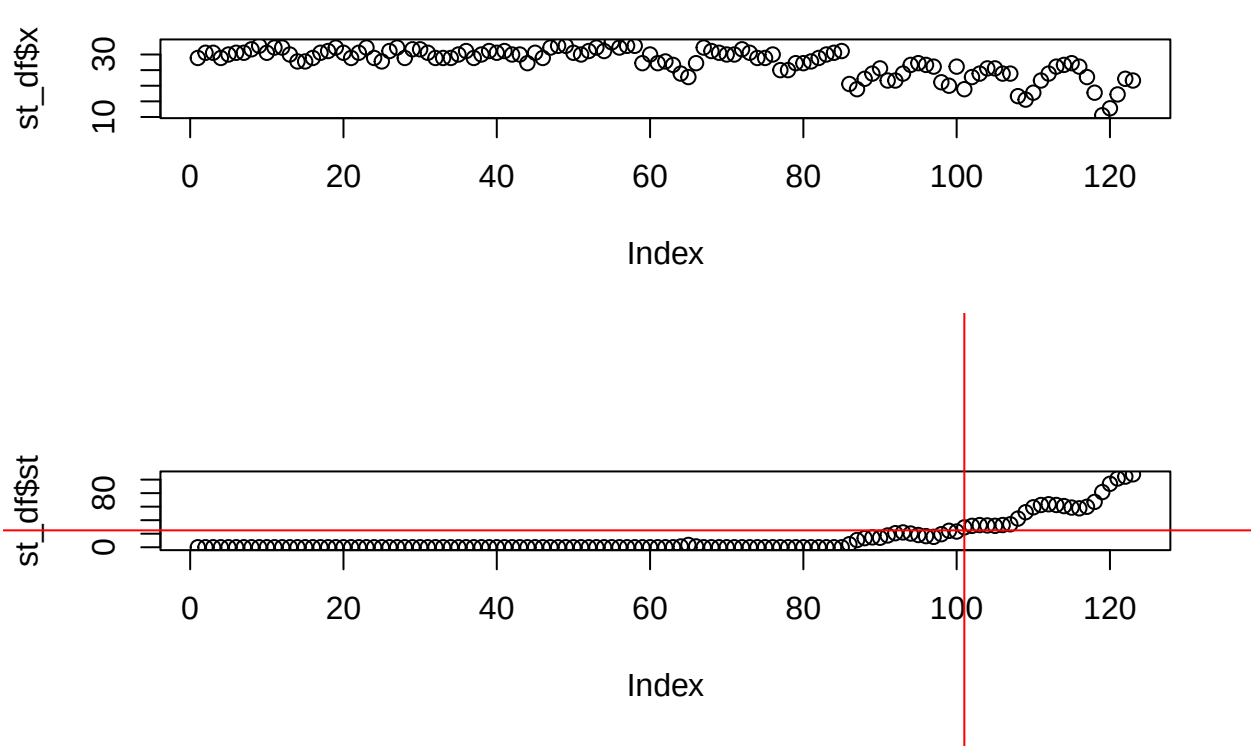
Temperature (in Celsius) and S_t (bottom) for year 1997

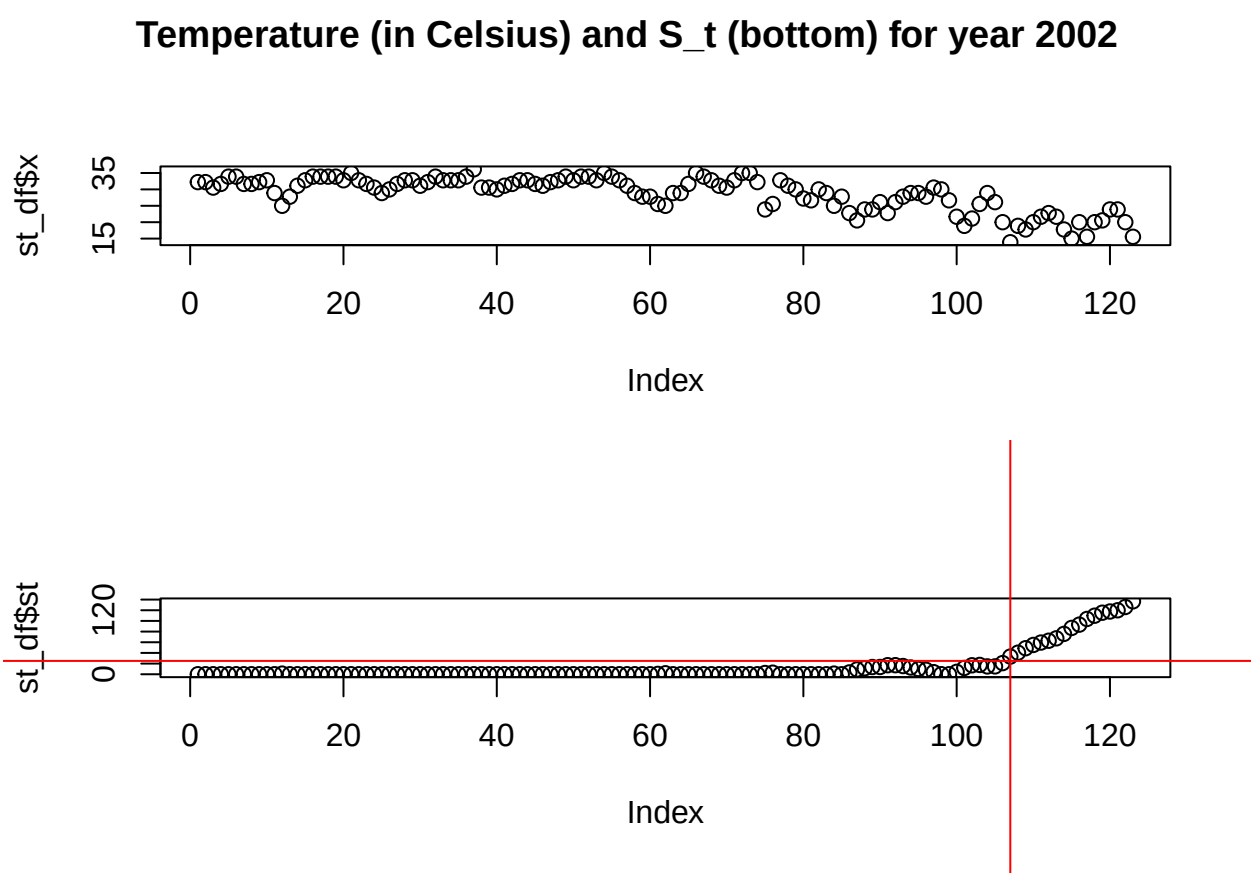


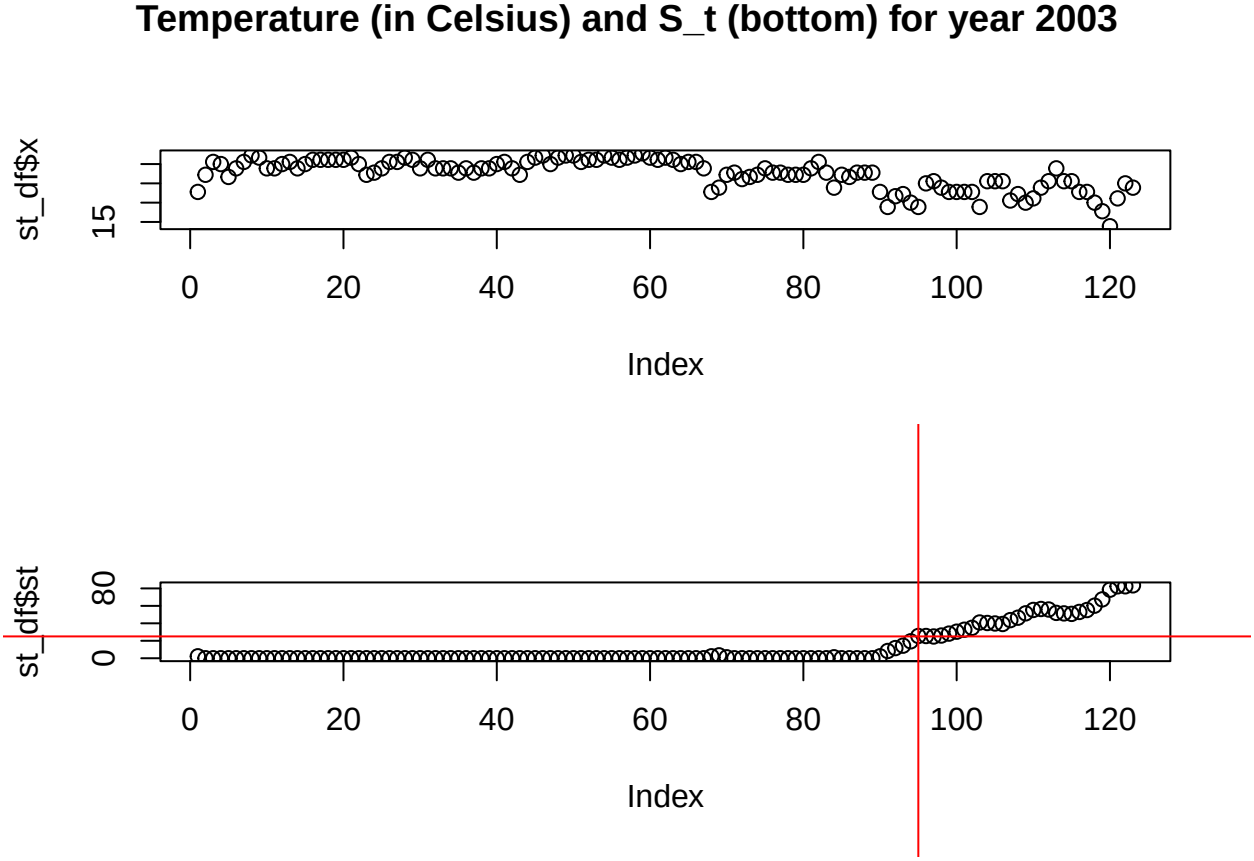

Temperature (in Celsius) and S_t (bottom) for year 1998
st_df$x
20
0
20
40
60
80
100
120
Index
st_df$st
0
50
0
20
40
60
80
100
120
Index

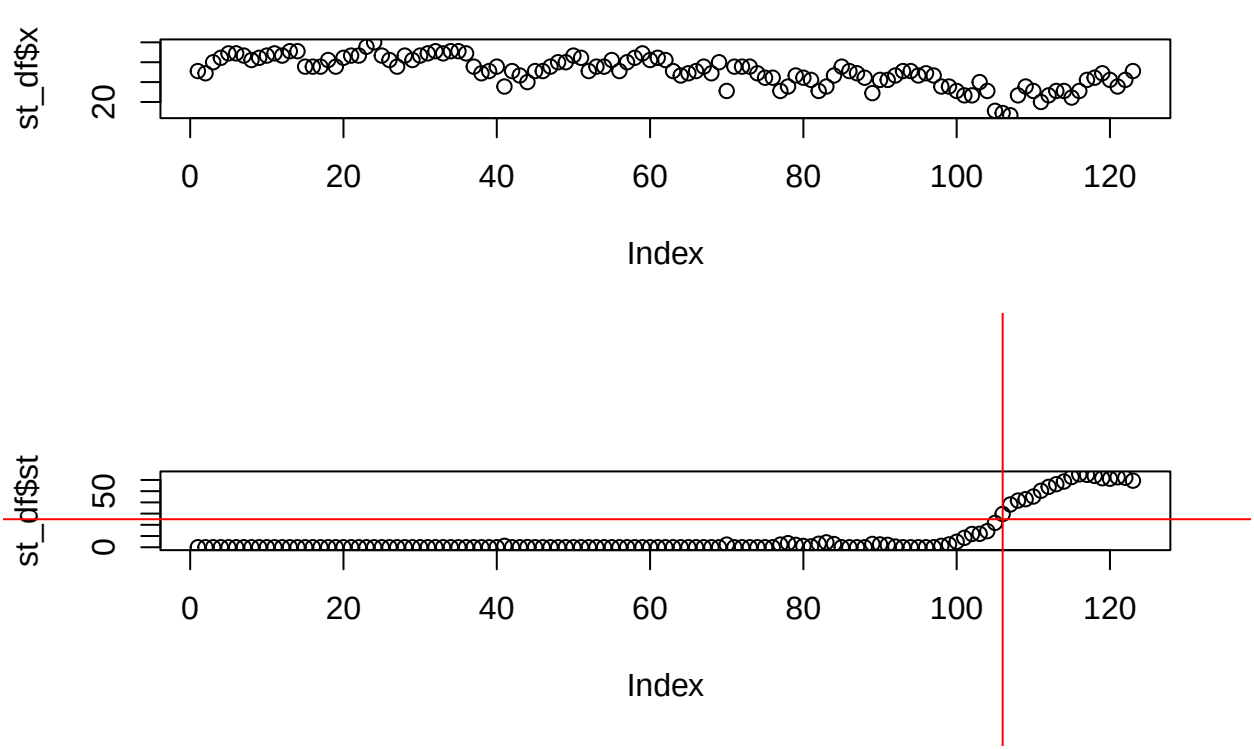

Temperature (in Celsius) and S_t (bottom) for year 1999
st_df$x
15
35
0
20
40
60
80
100
120
Index
st_df$st
0
150
0
20
40
60
80
100
120
Index

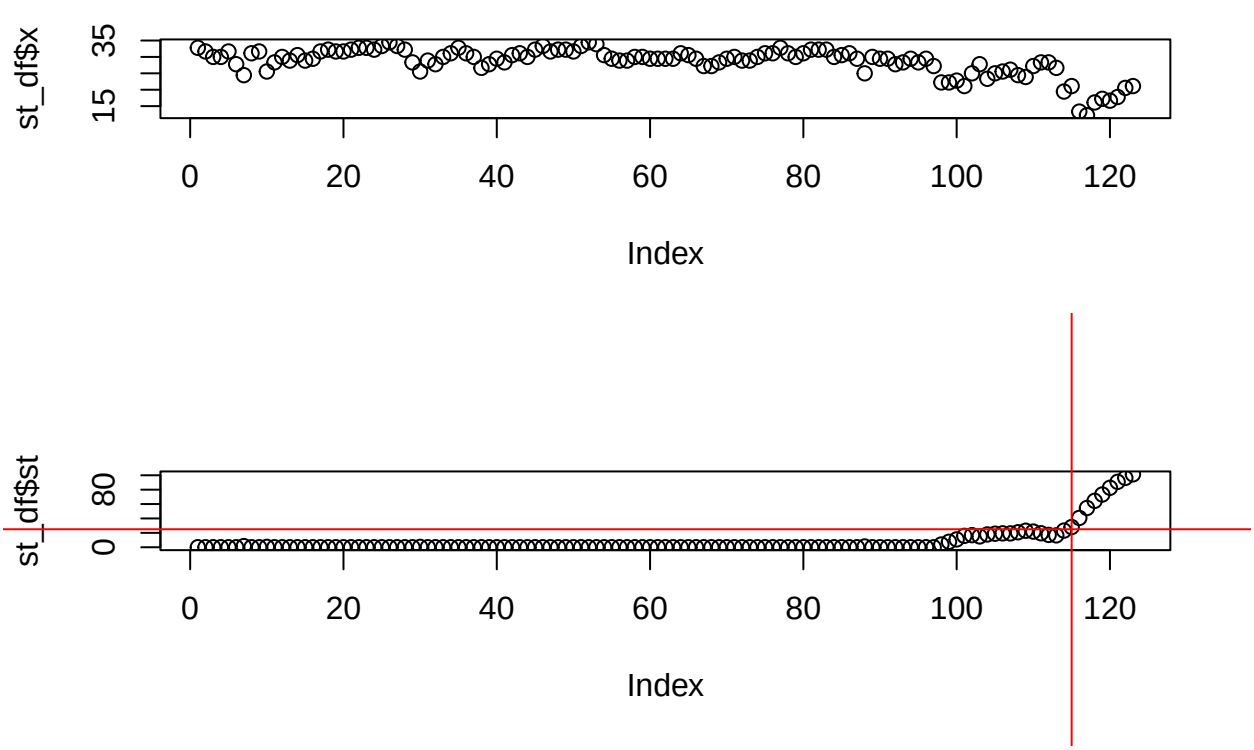

Temperature (in Celsius) and S_t (bottom) for year 2000
st_df$x
15
0
20
40
60
80
100
120
Index
st_df$st
0
80
0
20
40
60
80
100
120
Index

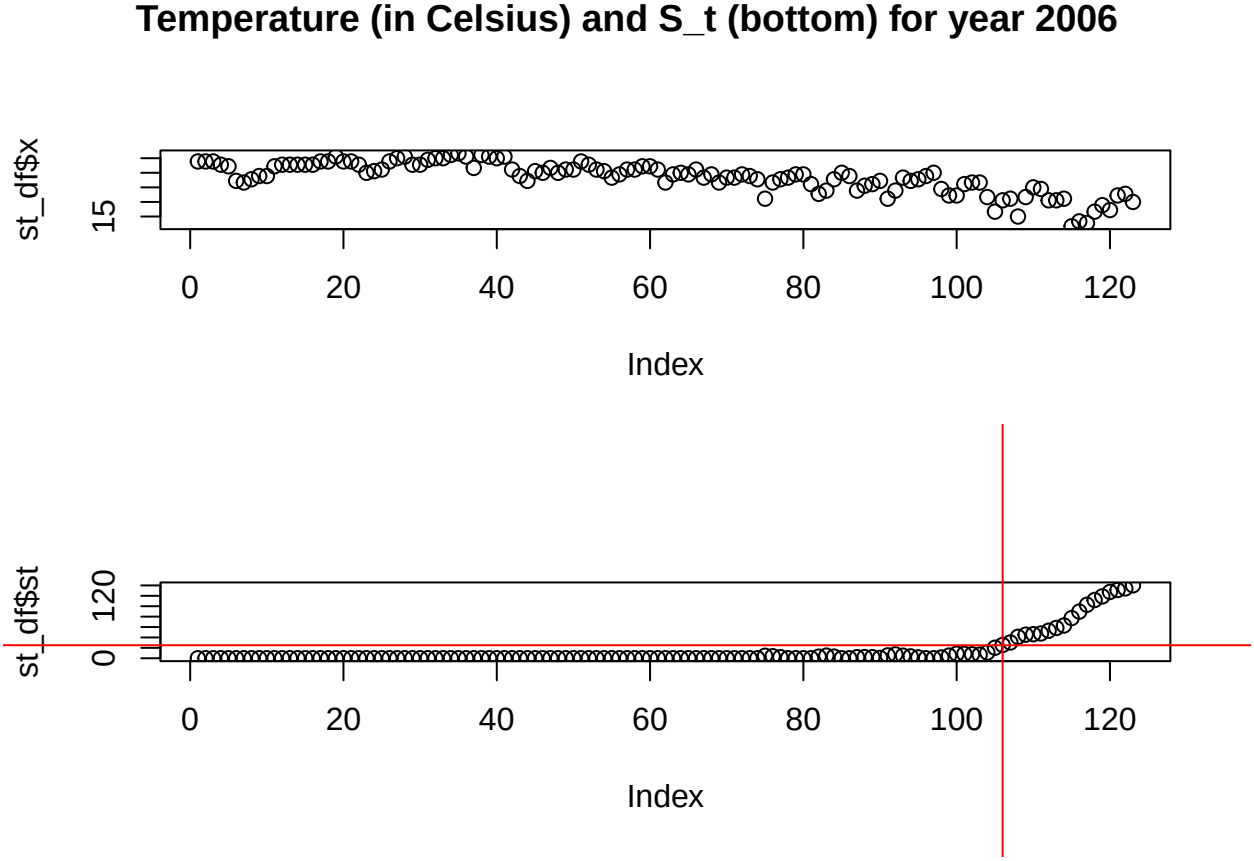

Temperature (in Celsius) and S_t (bottom) for year 2001
st_df$x
10
30
0
20
40
60
80
100
120
Index
st_df$st
0
80
0
20
40
60
80
100
120
Index

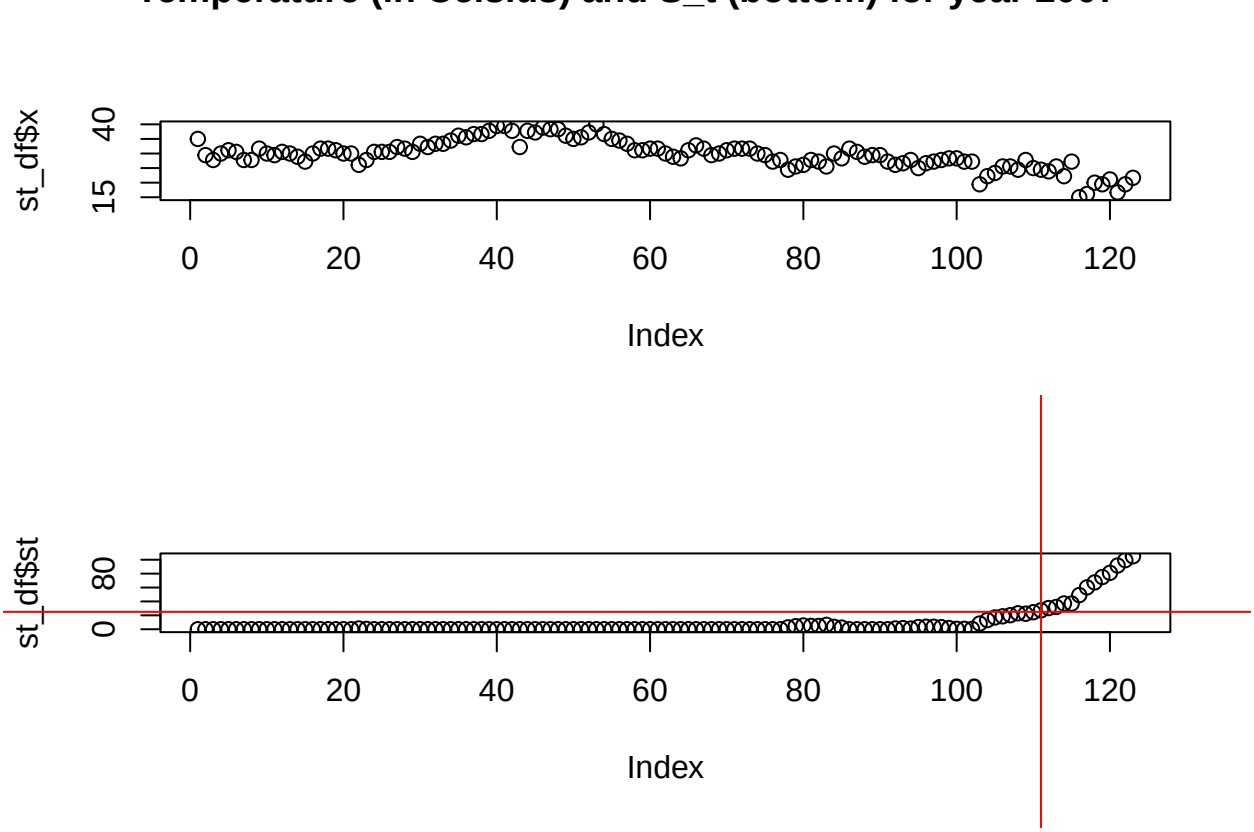

Temperature (in Celsius) and S_t (bottom) for year 2002
st_df$x
15
35
0
20
40
60
80
100
120
Index
st_df$st
0
120
0
20
40
60
80
100
120
Index

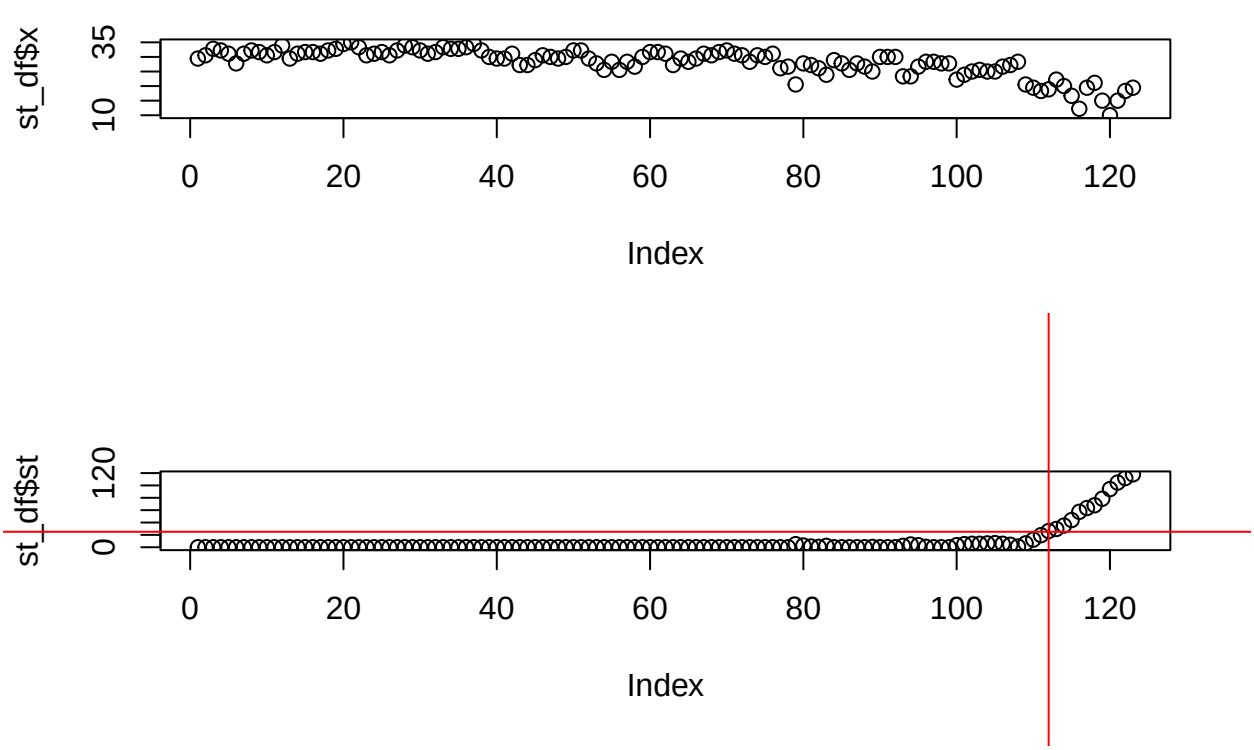

Temperature (in Celsius) and S_t (bottom) for year 2003
st_df$x
15
0
20
40
60
80
100
120
Index
st_df$st
80
0
0
20
40
60
80
100
120
Index

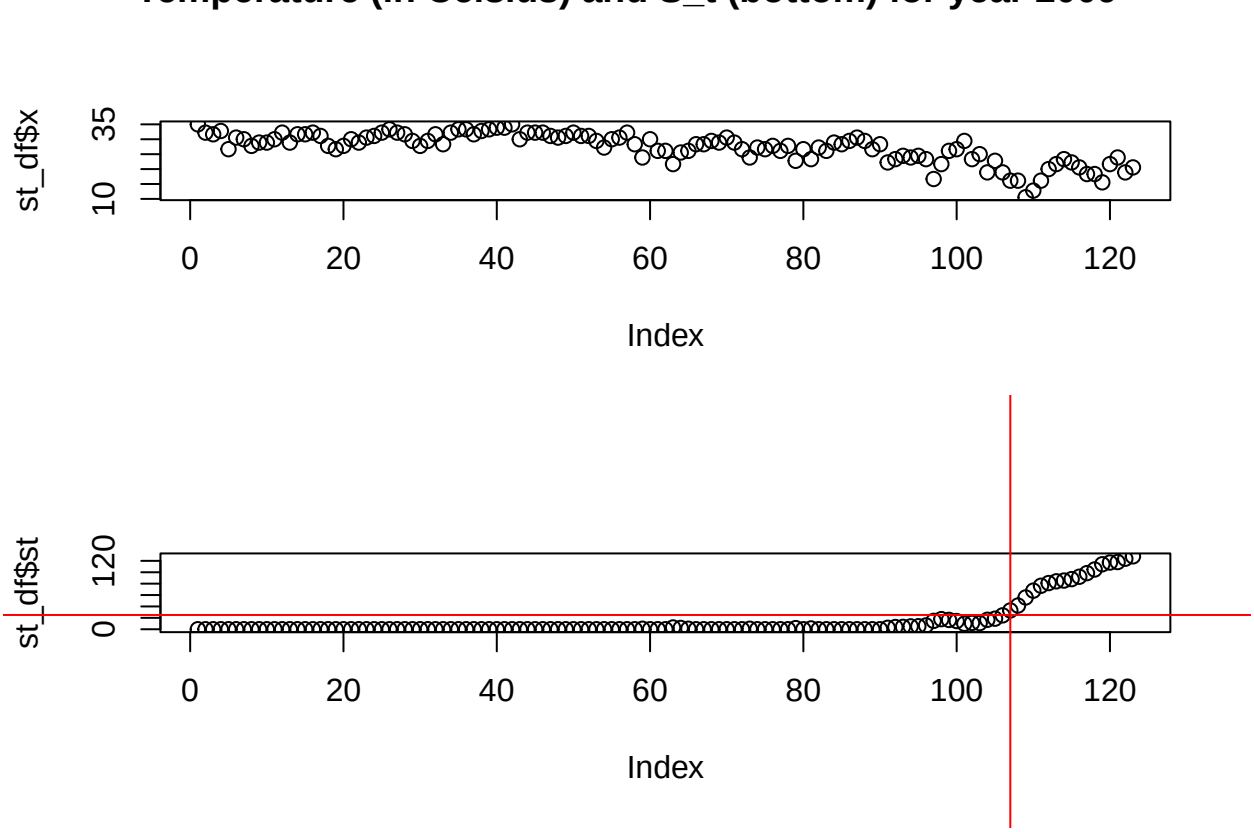

Temperature (in Celsius) and S_t (bottom) for year 2004
st_df$x
20
0
20
40
60
80
100
120
Index
st_df$st
0
50
0
20
40
60
80
100
120
Index

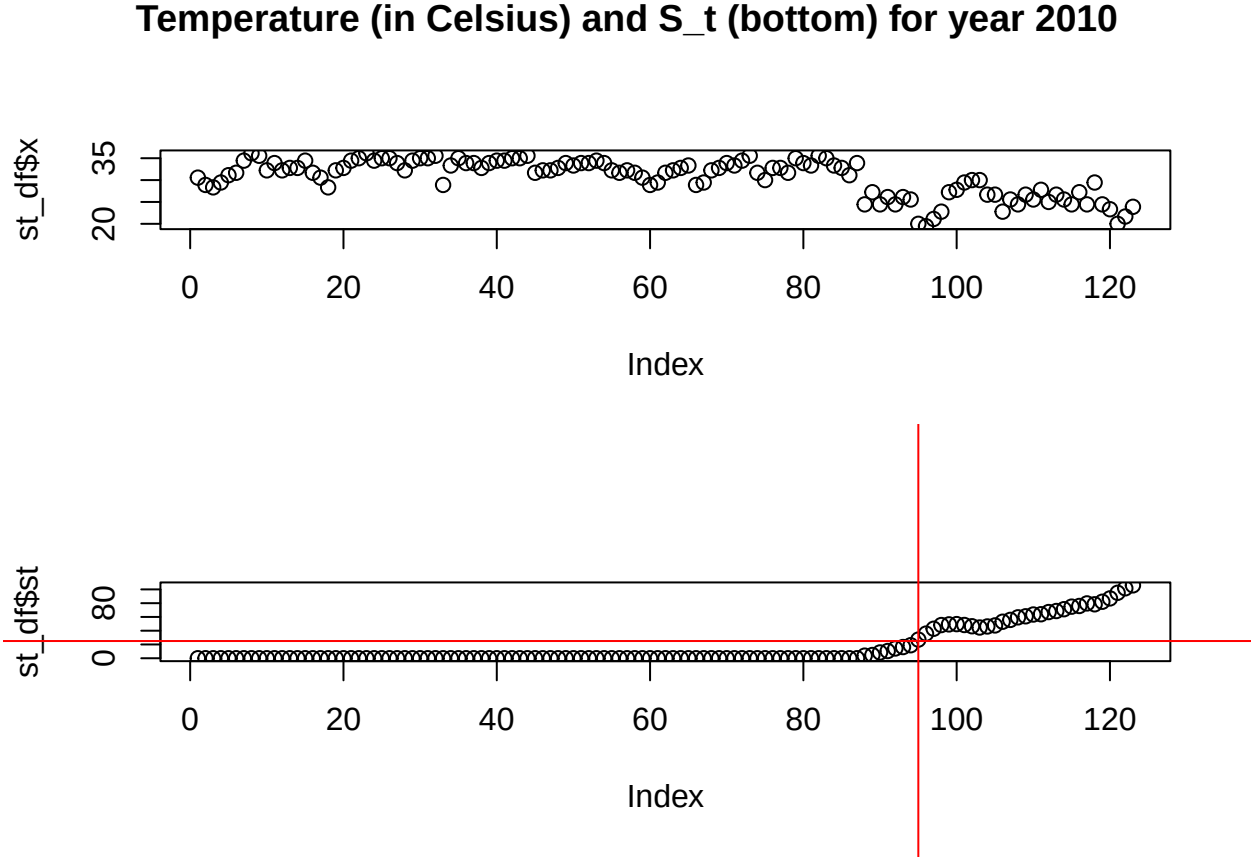

Temperature (in Celsius) and S_t (bottom) for year 2005
st_df$x
15
35
0
20
40
60
80
100
120
Index
st_df$st
0
80
0
20
40
60
80
100
120
Index

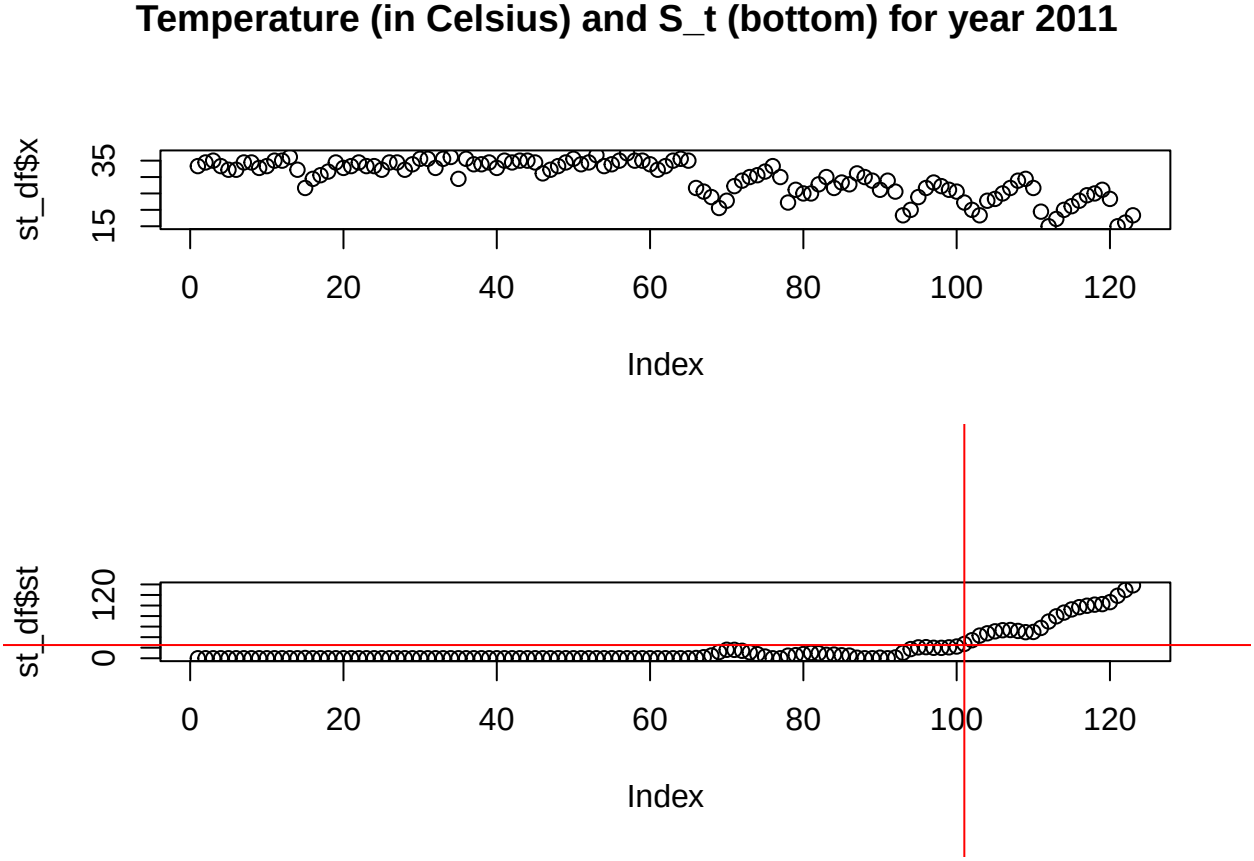

Temperature (in Celsius) and S_t (bottom) for year 2006
st_df$x
15
0
20
40
60
80
100
120
Index
st_df$st
0
120
0
20
40
60
80
100
120
Index

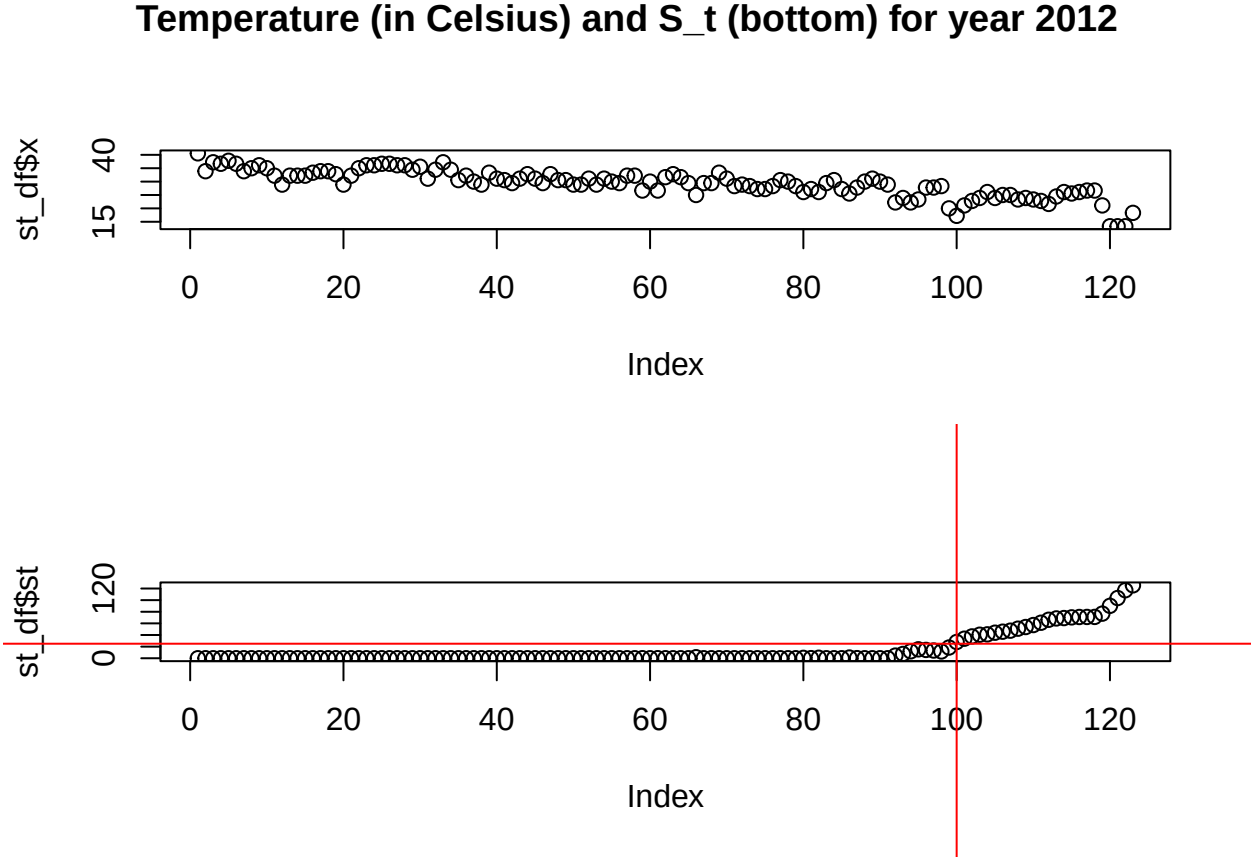

Temperature (in Celsius) and S_t (bottom) for year 2007
st_df$x
15
40
0
20
40
60
80
100
120
Index
st_df$st
0
80
0
20
40
60
80
100
120
Index

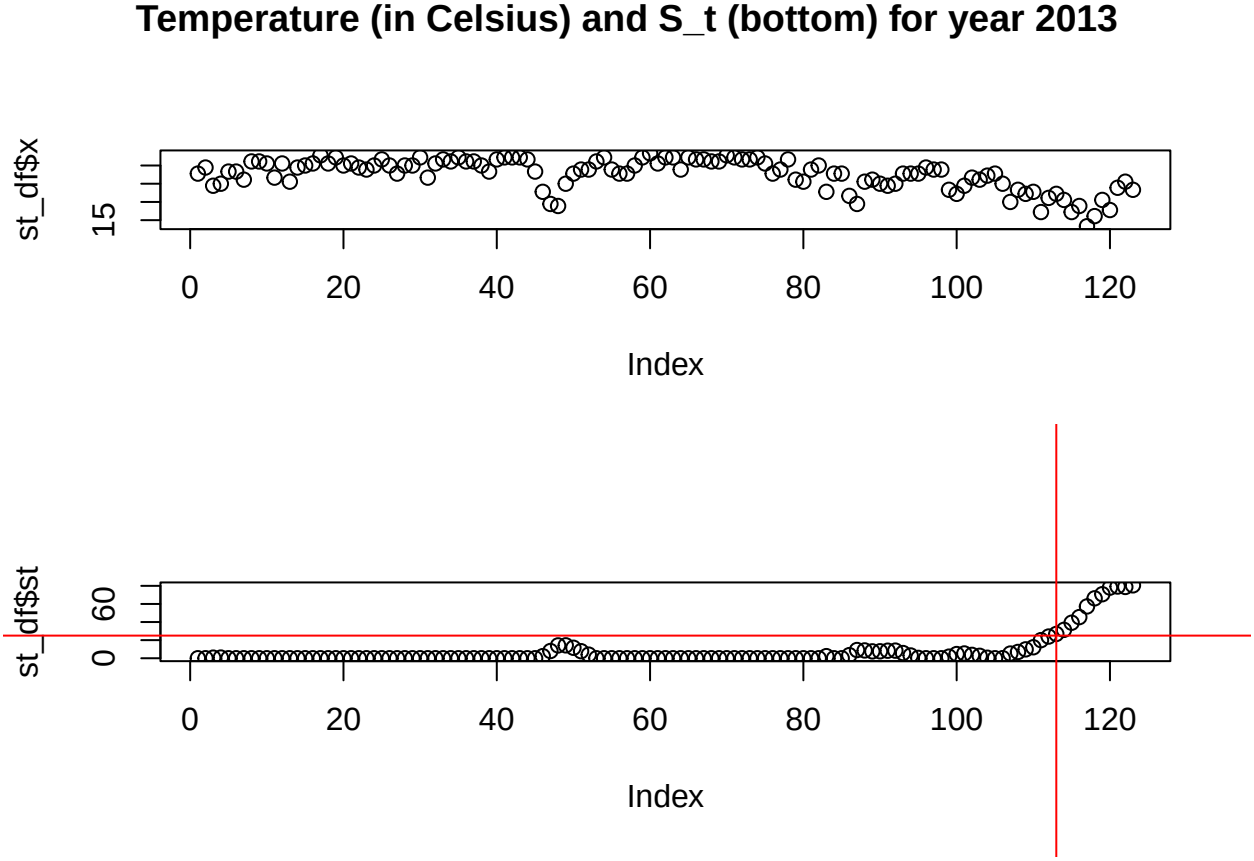

Temperature (in Celsius) and S_t (bottom) for year 2008
st_df$x
10
35
0
20
40
60
80
100
120
Index
st_df$st
0
120
0
20
40
60
80
100
120
Index

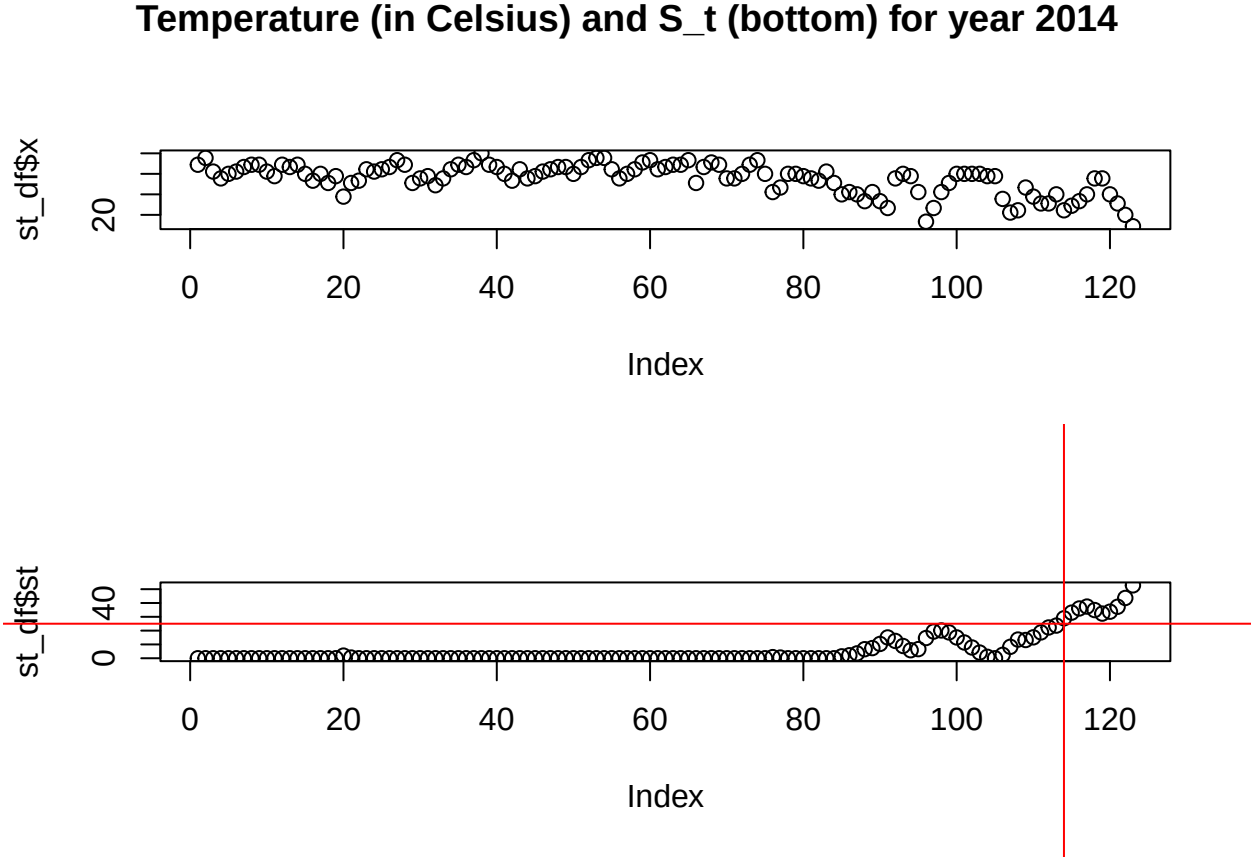

Temperature (in Celsius) and S_t (bottom) for year 2009
st_df$x
10
35
0
20
40
60
80
100
120
Index
st_df$st
0
120
0
20
40
60
80
100
120
Index

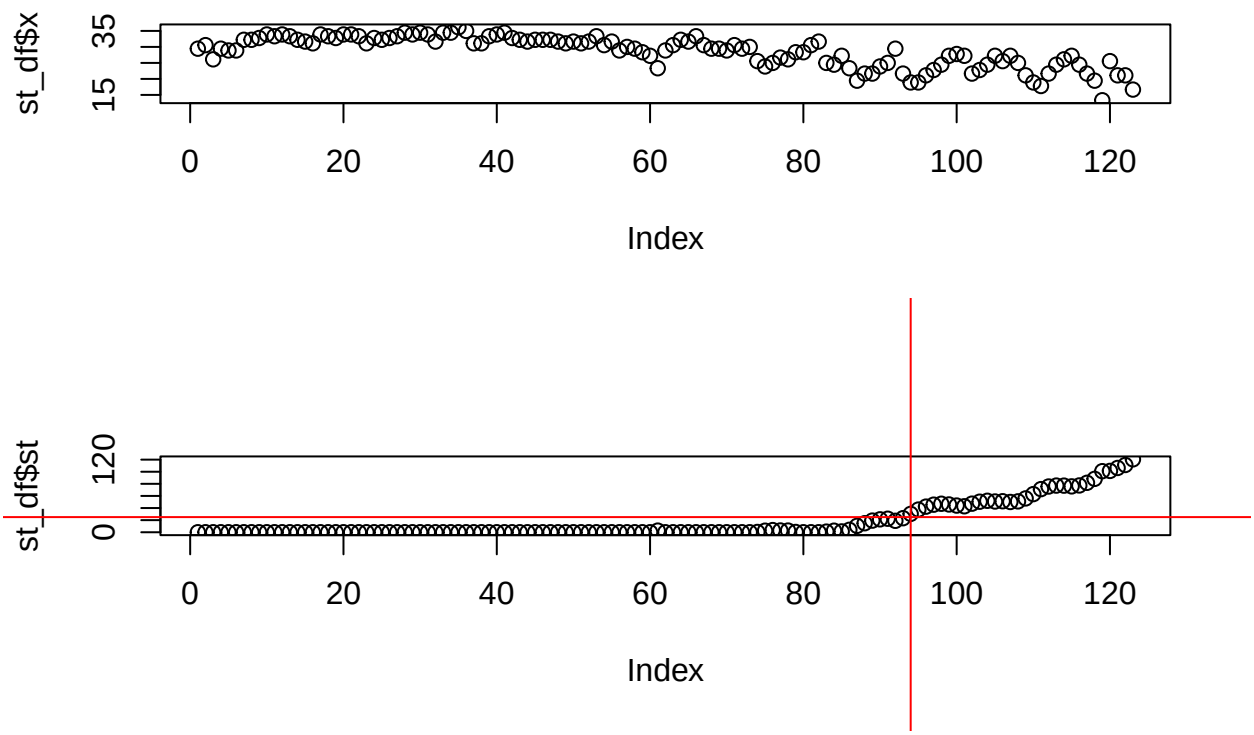

Temperature (in Celsius) and S_t (bottom) for year 2010
st_df$x
20
35
0
20
40
60
80
100
120
Index
st_df$st
0
80
0
20
40
60
80
100
120
Index


Temperature (in Celsius) and S_t (bottom) for year 2011
st_df$x
15
35
0
20
40
60
80
100
120
Index
st_df$st
0
120
0
20
40
60
80
100
120
Index


Temperature (in Celsius) and S_t (bottom) for year 2012
st_df$x
15
40
0
20
40
60
80
100
120
Index
st_df$st
0
120
0
20
40
60
80
100
120
Index

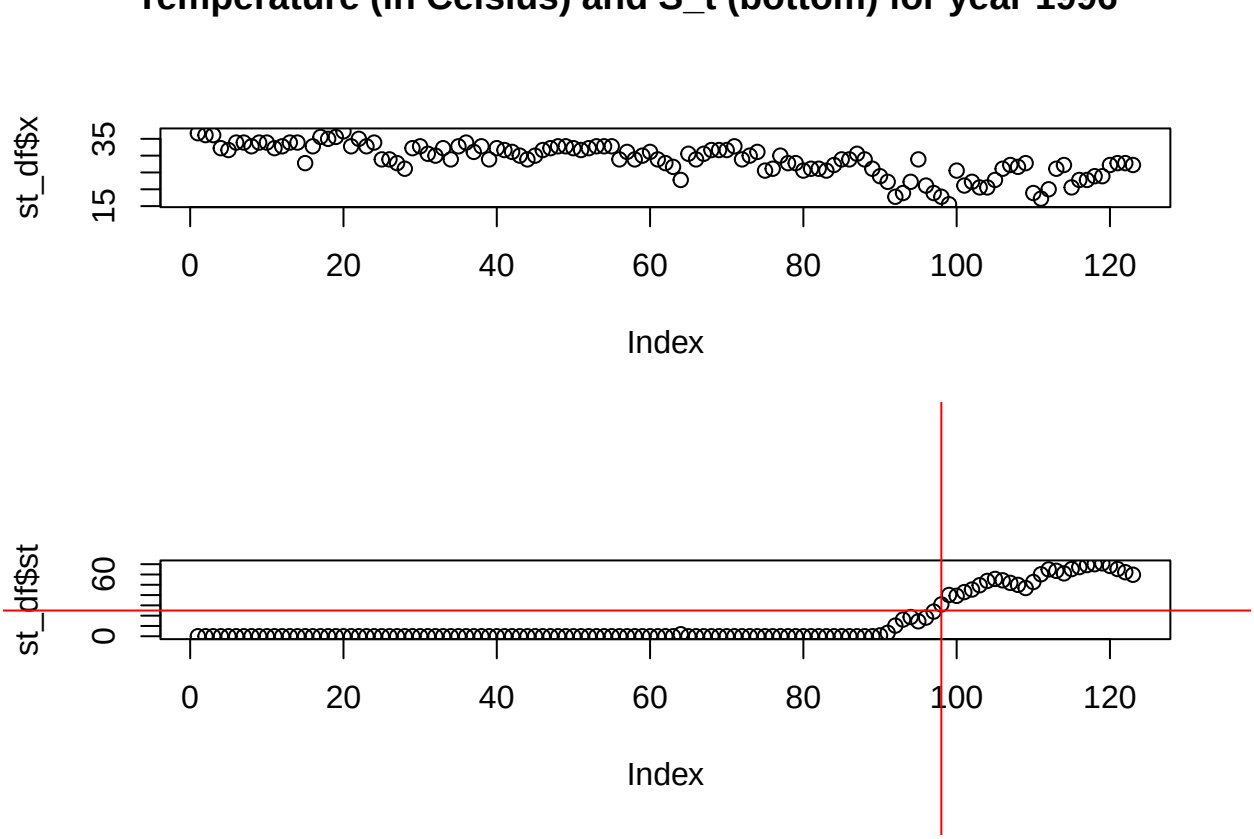

Temperature (in Celsius) and S_t (bottom) for year 2013
st_df$x
15
0
20
40
60
80
100
120
Index
st_df$st
0
60
0
20
40
60
80
100
120
Index

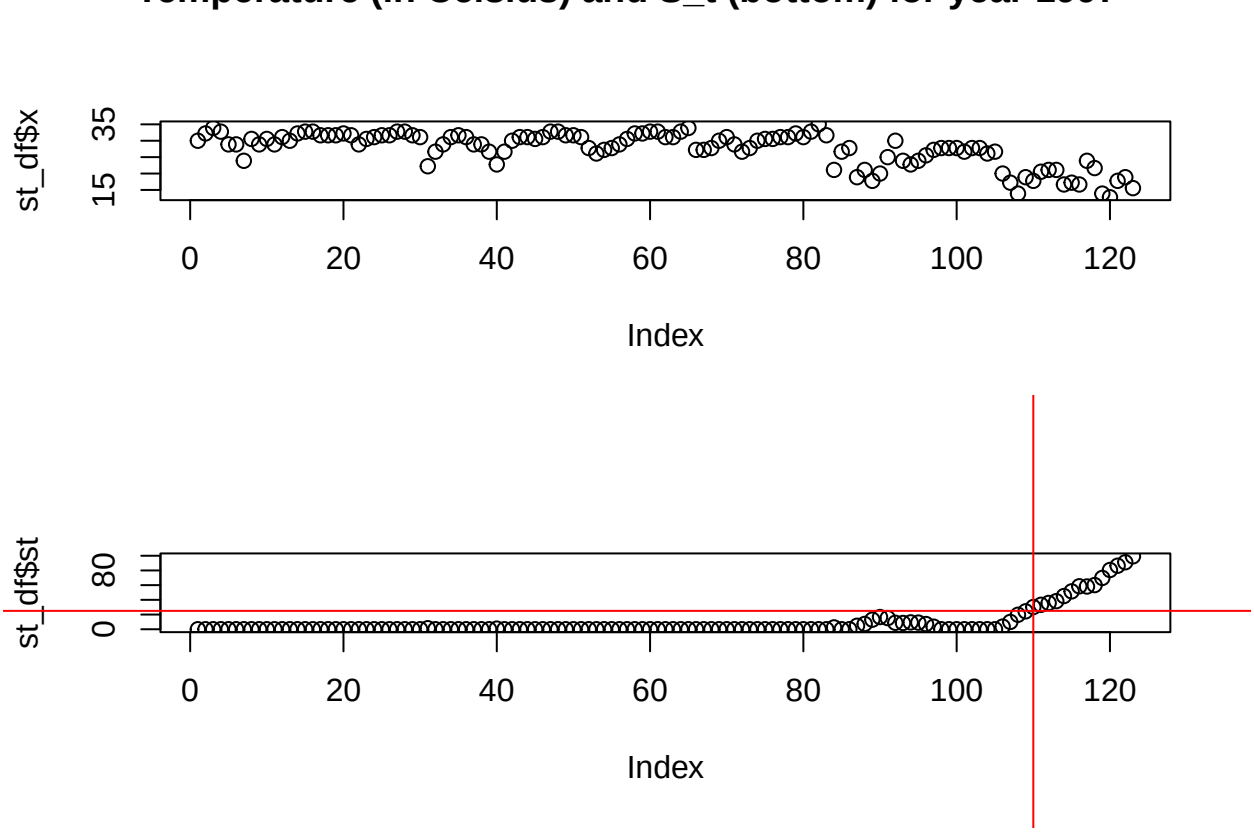

Temperature (in Celsius) and S_t (bottom) for year 2014
st_df$x
20
0
20
40
60
80
100
120
Index
st_df$st
0
40
0
20
40
60
80
100
120
Index

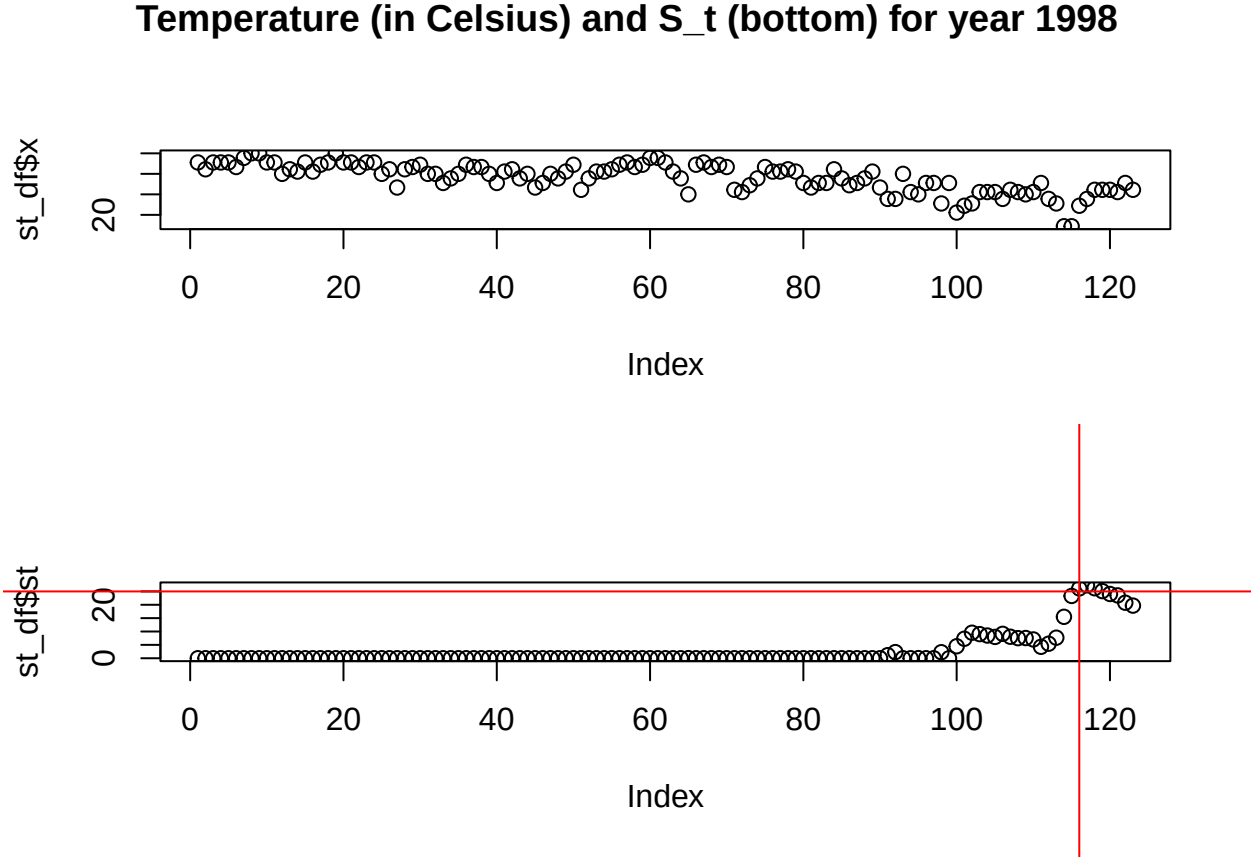


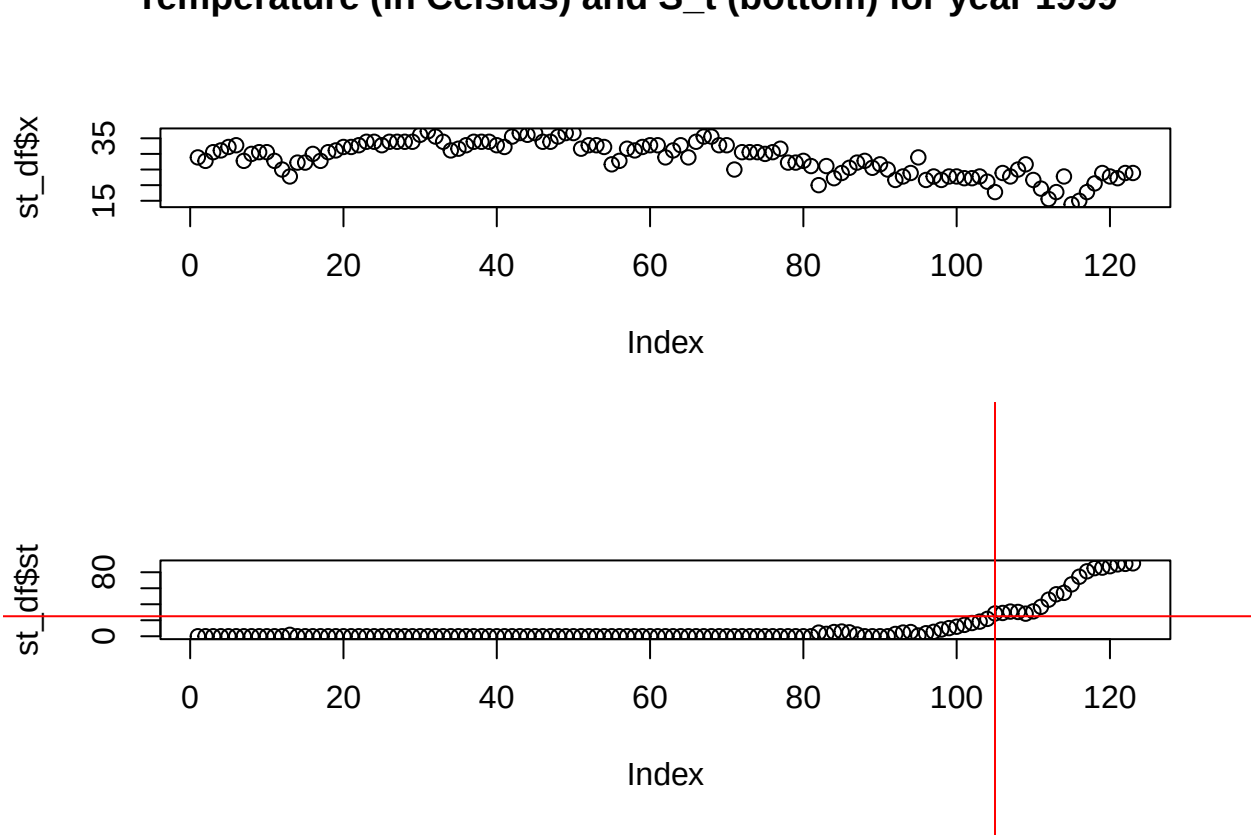

```
# barplot(sapply(winter_start_days,"[[",1),
# main = "Variation of Winter Start from 1996 to 2015",
# xlab = "Year",
# ylab = "Days since Jul 1, when winter change detected",
# names.arg = temp_cols,
# col = "darkred",
# horiz = FALSE)
```

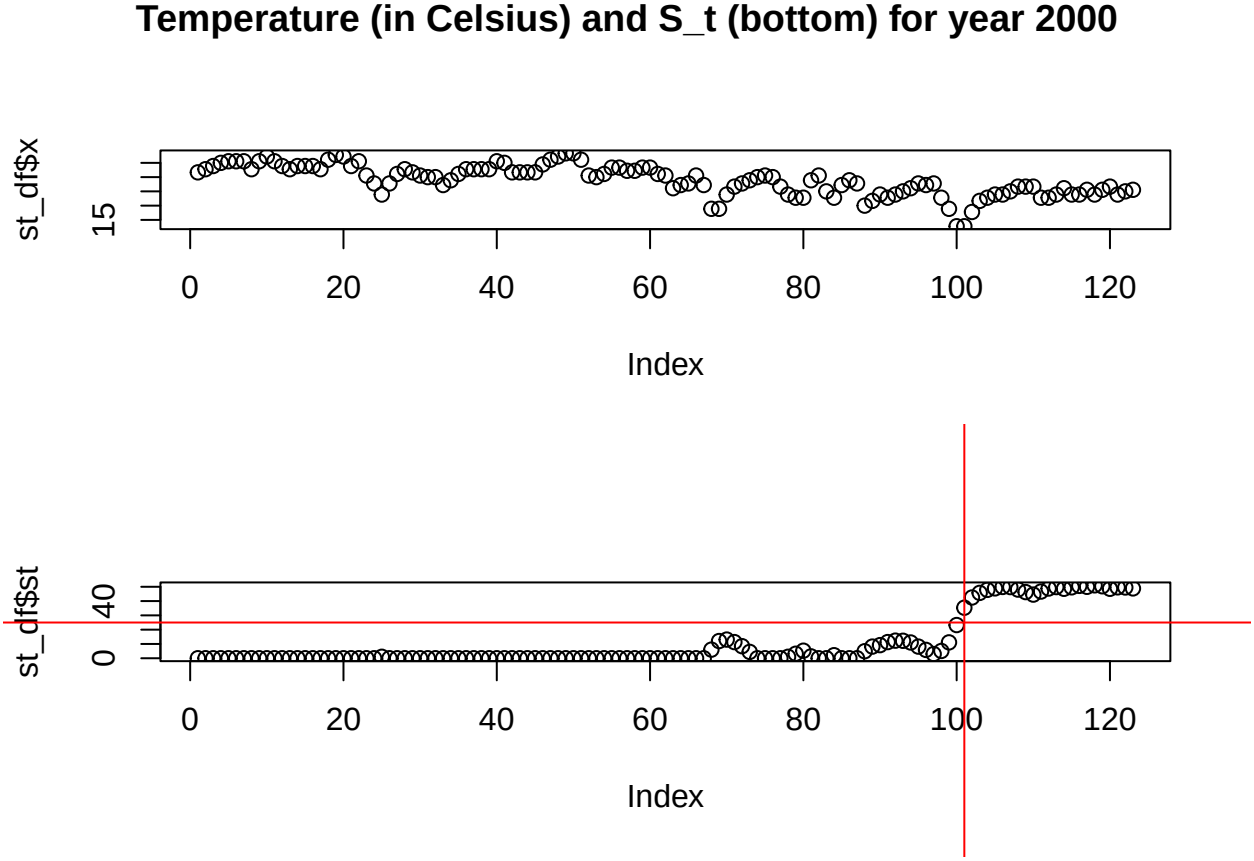
```
### Run Cusum over data_celsius for all the years
winter_start_days = lapply(temp_cols, function(col)
  CUSUM_ad(x=data_celsius[,col], year = substr(col,2,5), C = 4, T = 25)
  )
```

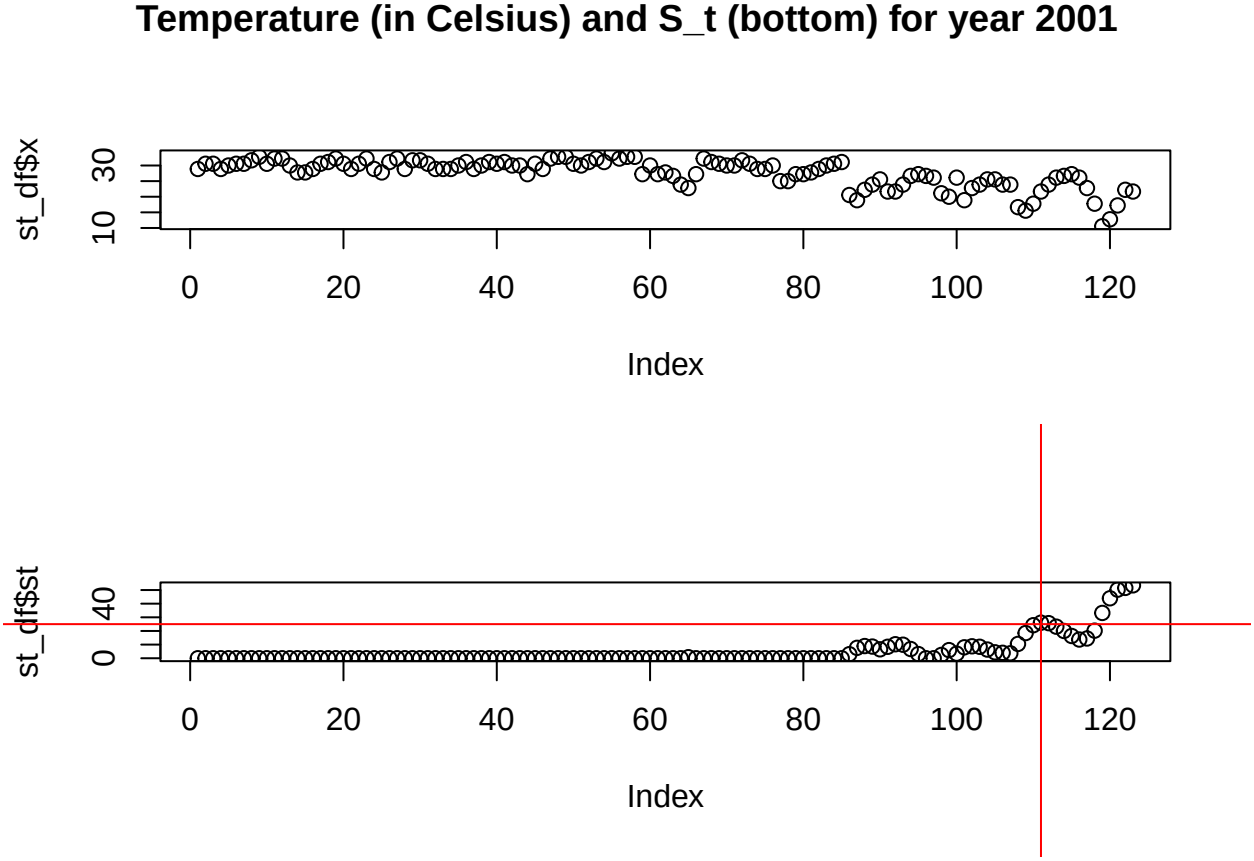

Temperature (in Celsius) and S_t (bottom) for year 1996
st_df$x
15
35
0
20
40
60
80
100
120
Index
st_df$st
0
60
0
20
40
60
80
100
120
Index

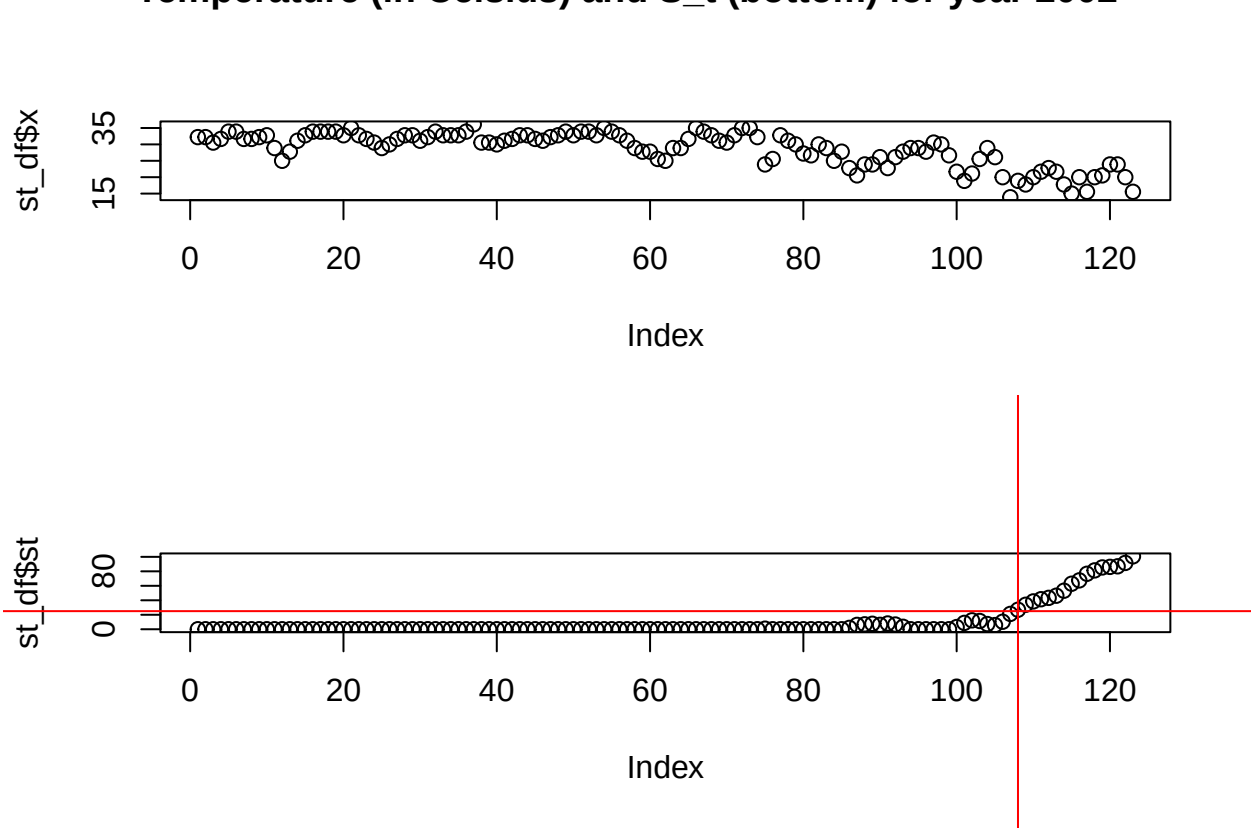

Temperature (in Celsius) and S_t (bottom) for year 1997
st_df$x
15
35
0
20
40
60
80
100
120
Index
st_df$st
0
80
0
20
40
60
80
100
120
Index

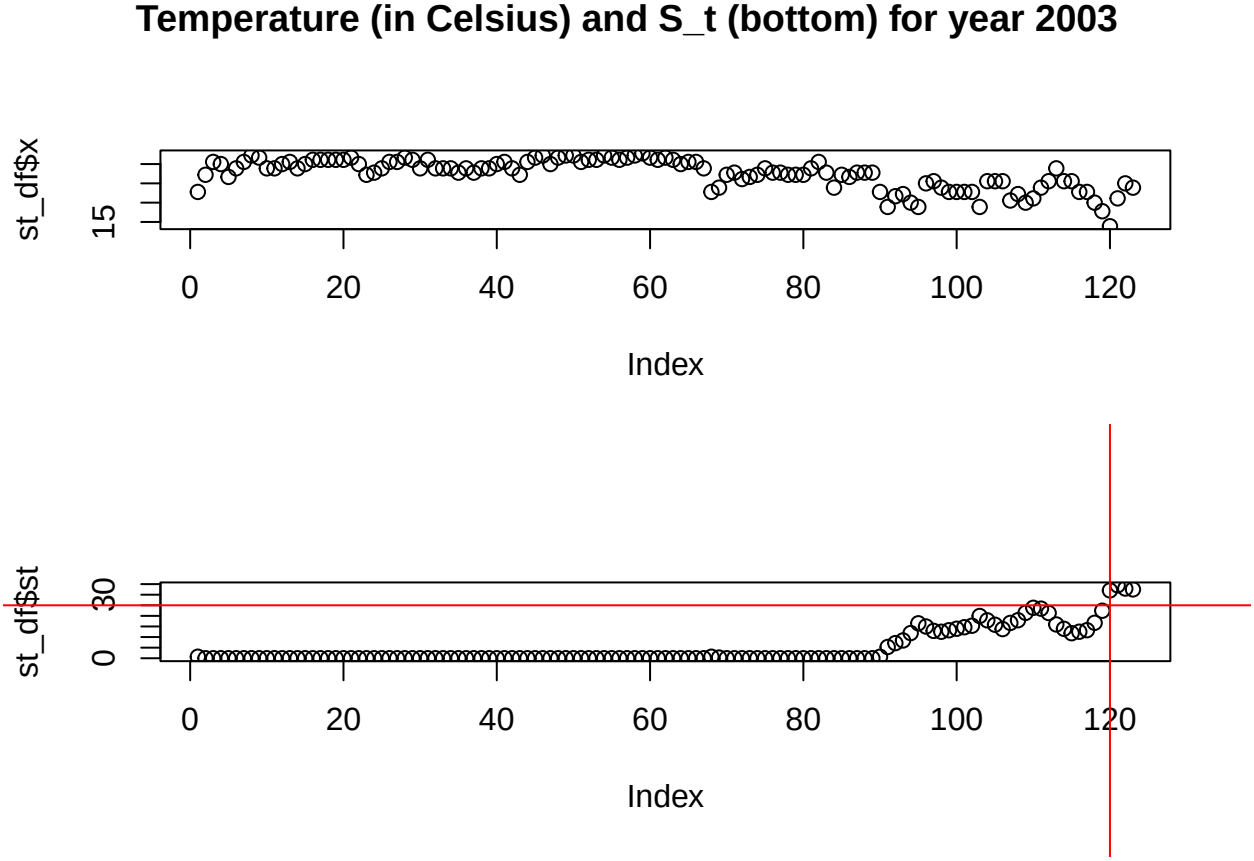

Temperature (in Celsius) and S_t (bottom) for year 1998
st_df$x
20
0
20
40
60
80
100
120
Index
st_df$st
0
20
0
20
40
60
80
100
120
Index

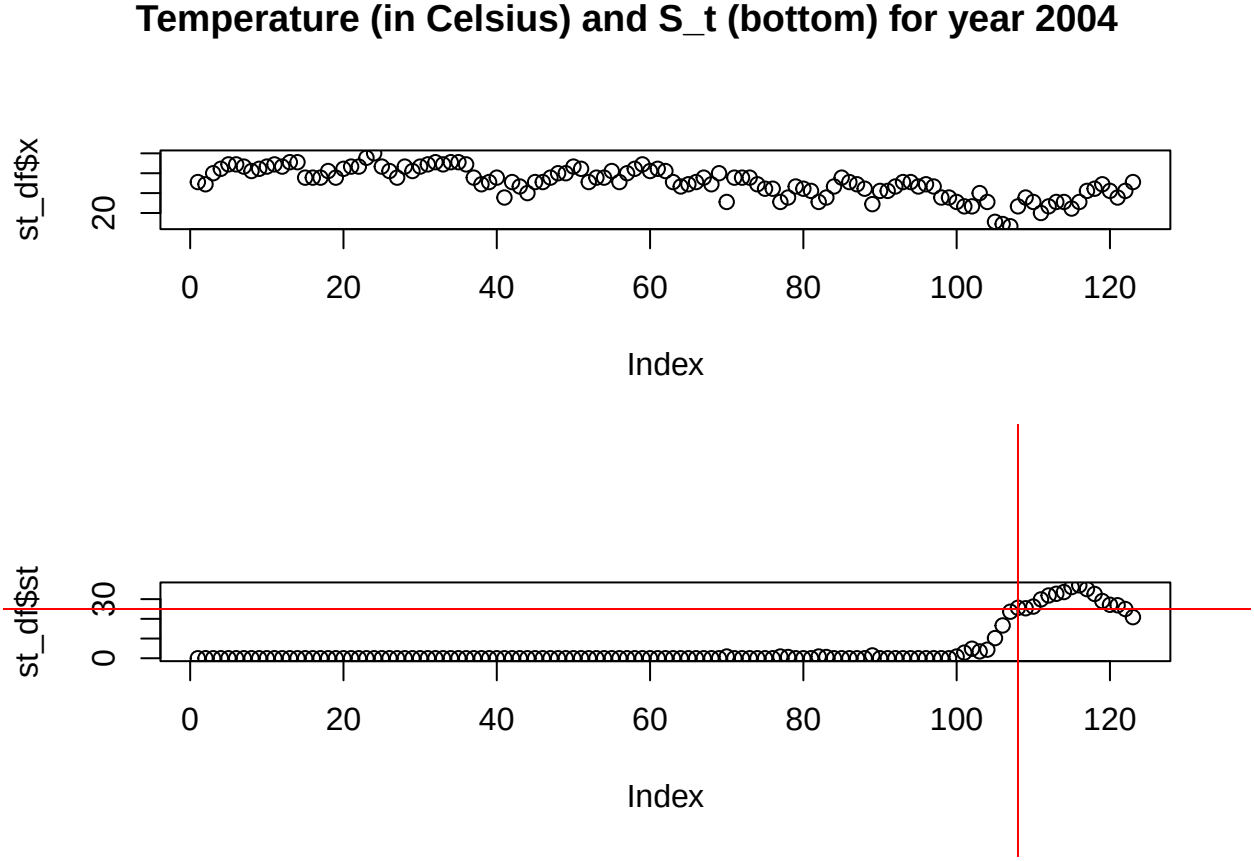

Temperature (in Celsius) and S_t (bottom) for year 1999
st_df$x
15
35
0
20
40
60
80
100
120
Index
st_df$st
0
80
0
20
40
60
80
100
120
Index

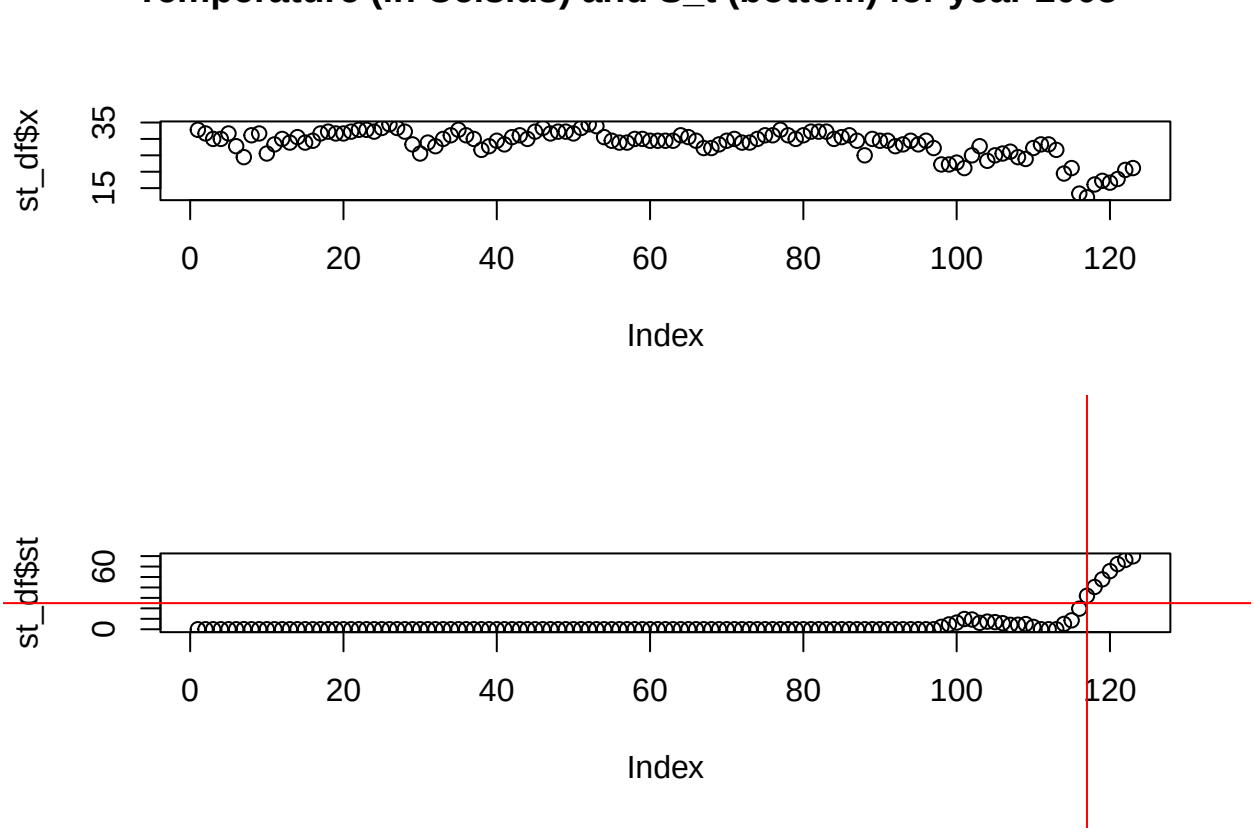

Temperature (in Celsius) and S_t (bottom) for year 2000
st_df$x
15
0
20
40
60
80
100
120
Index
st_df$st
0
40
0
20
40
60
80
100
120
Index

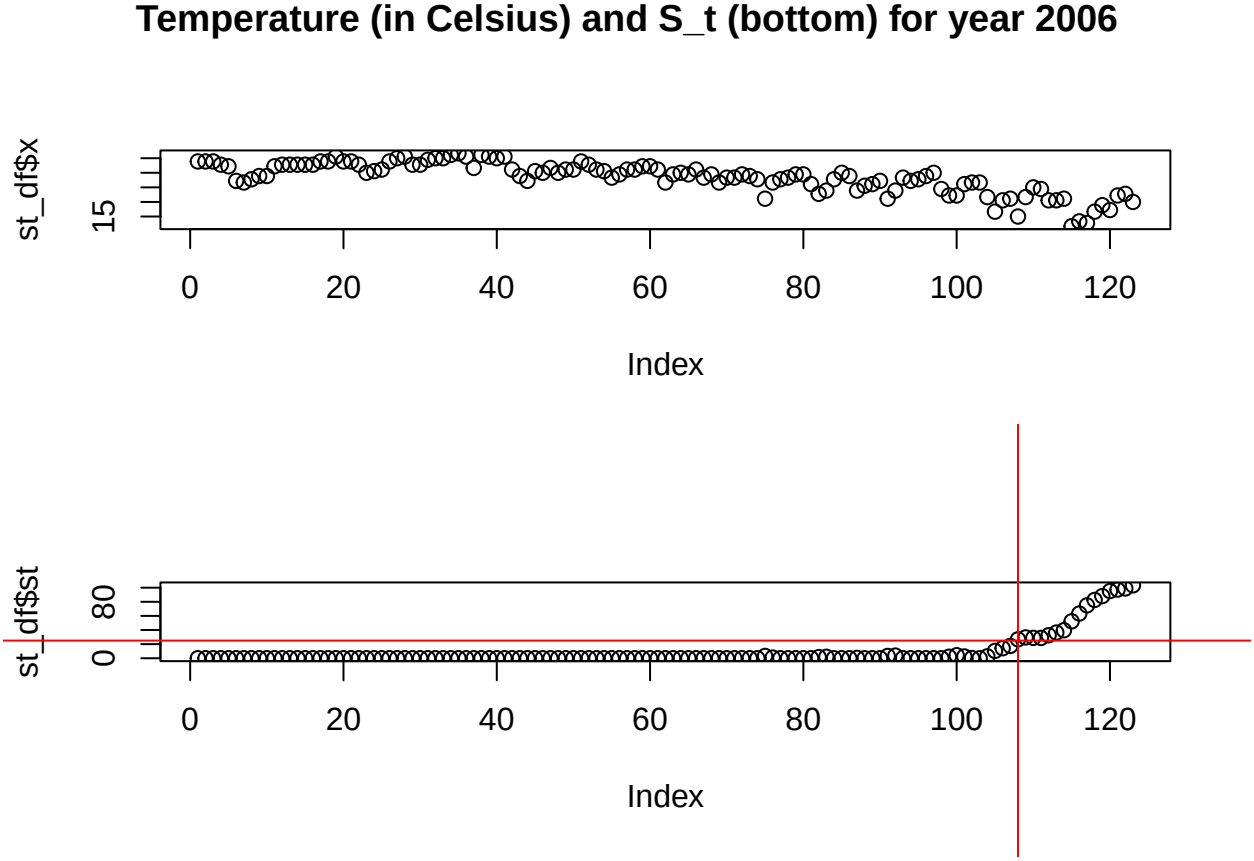

Temperature (in Celsius) and S_t (bottom) for year 2001
st_df$x
10
30
0
20
40
60
80
100
120
Index
st_df$st
0
40
0
20
40
60
80
100
120
Index

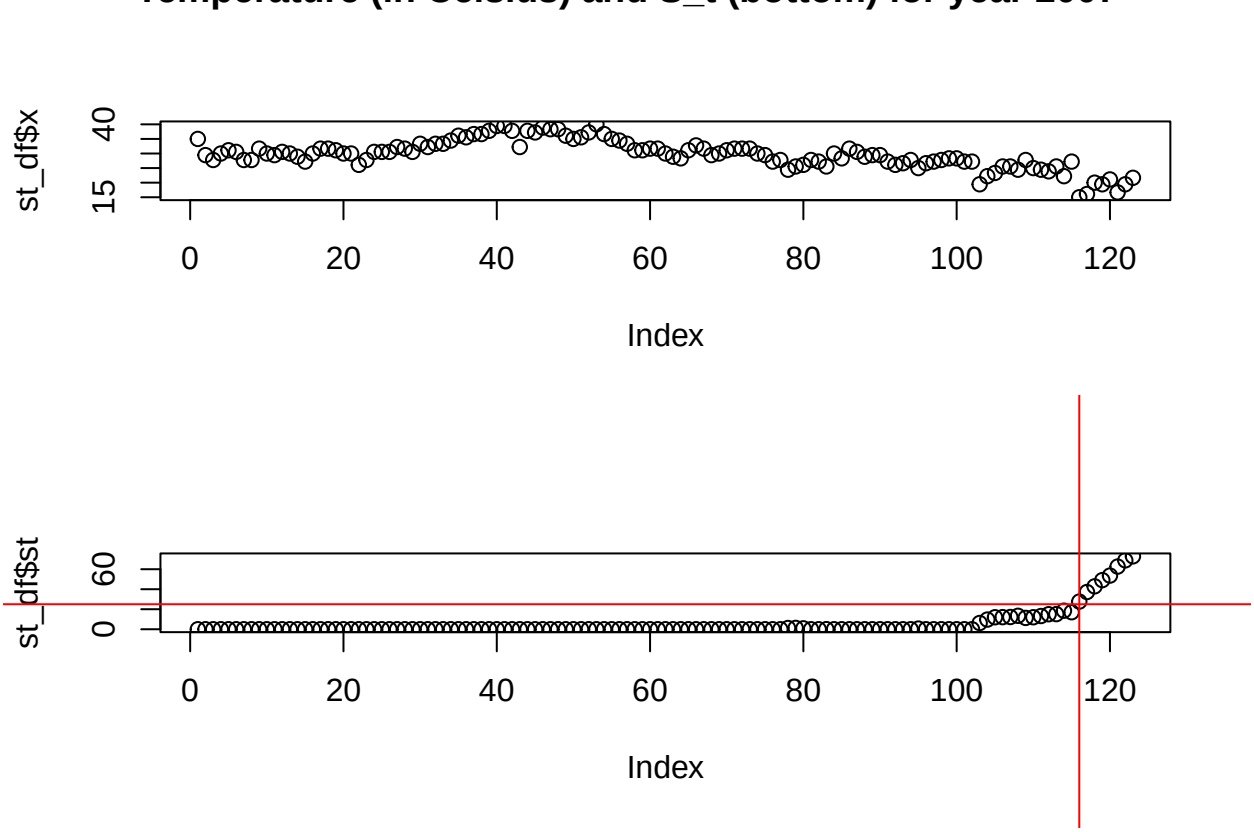

Temperature (in Celsius) and S_t (bottom) for year 2002
st_df$x
15
35
0
20
40
60
80
100
120
Index
st_df$st
0
80
0
20
40
60
80
100
120
Index

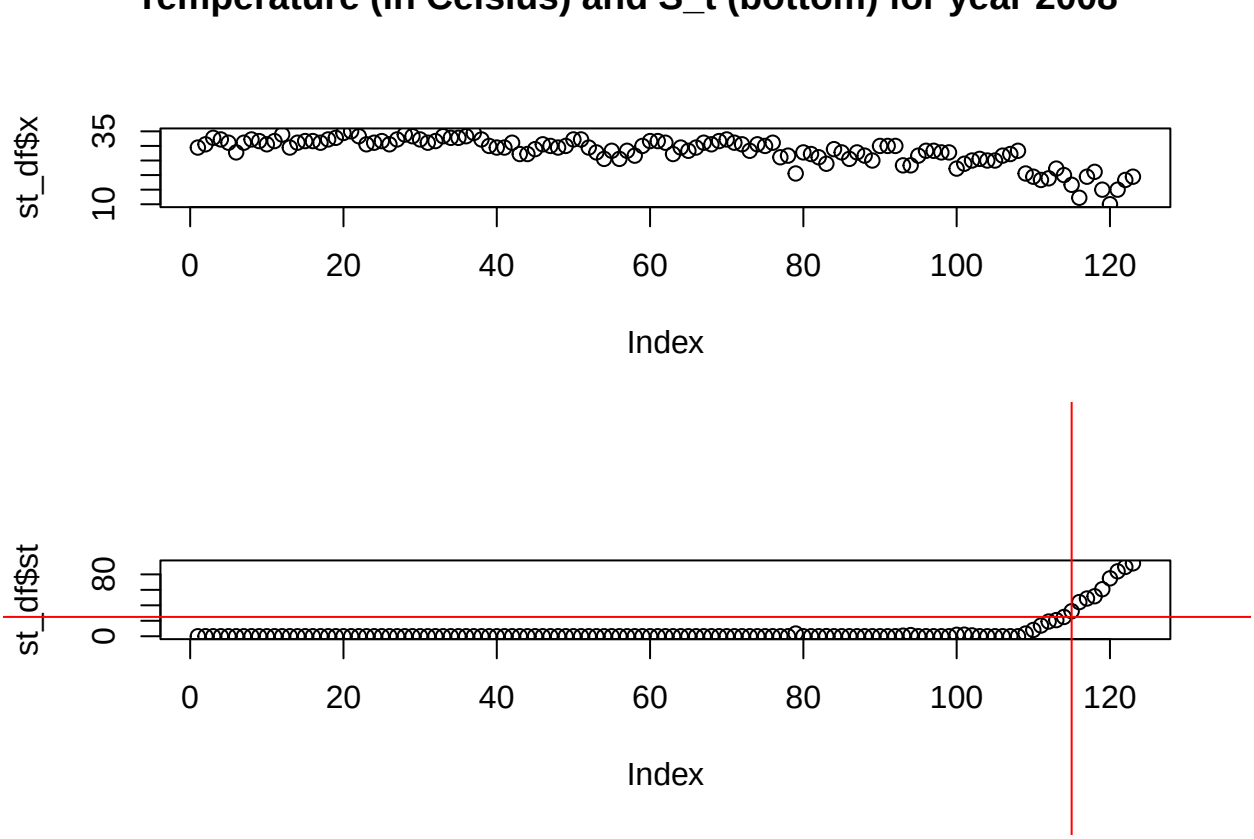

Temperature (in Celsius) and S_t (bottom) for year 2003
st_df$x
15
0
20
40
60
80
100
120
Index
st_df$st
0
30
0
20
40
60
80
100
120
Index

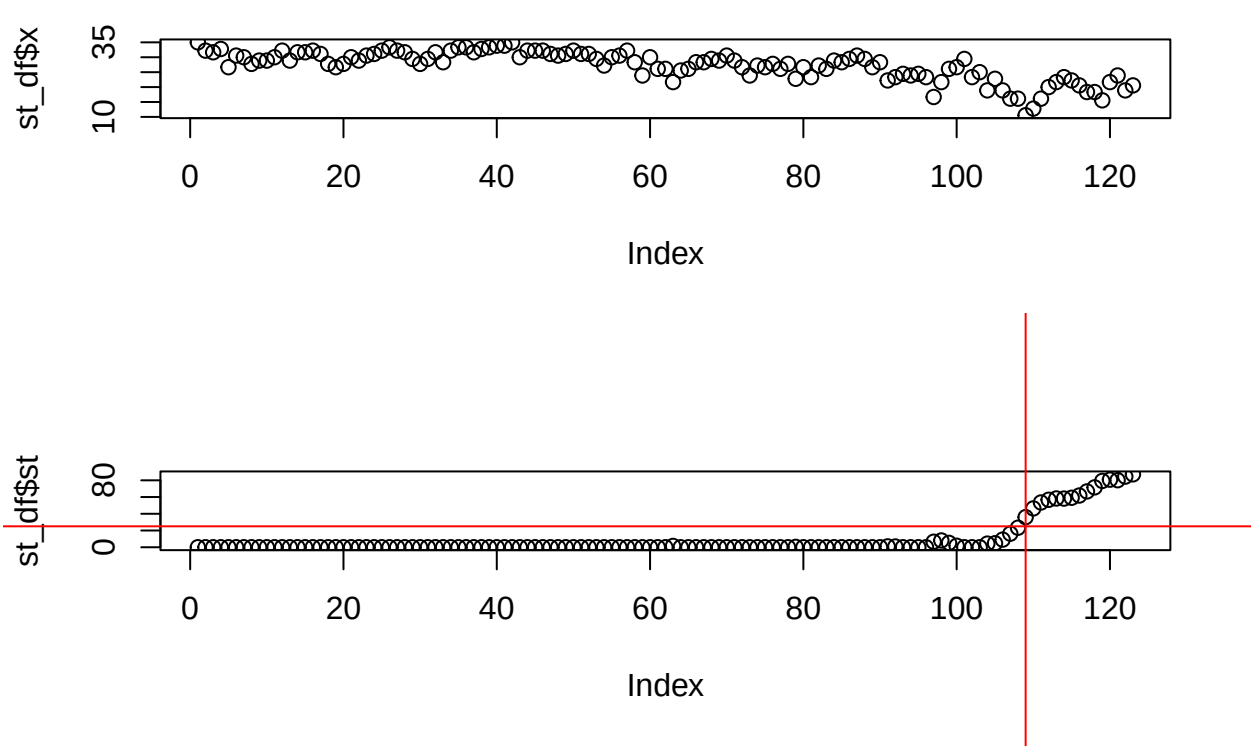

Temperature (in Celsius) and S_t (bottom) for year 2004
st_df$x
20
0
20
40
60
80
100
120
Index
st_df$st
0
30
0
20
40
60
80
100
120
Index

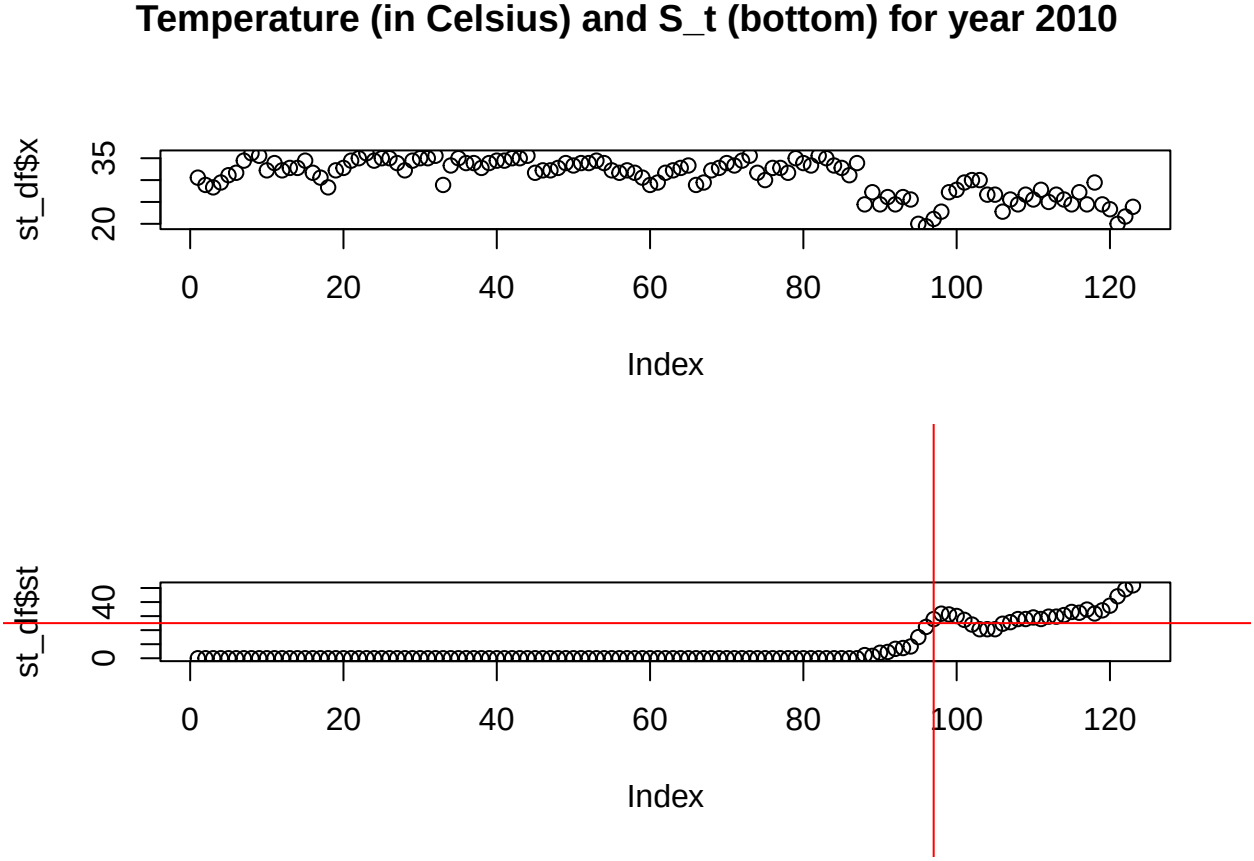

Temperature (in Celsius) and S_t (bottom) for year 2005
st_df$x
15
35
0
20
40
60
80
100
120
Index
st_df$st
0
60
0
20
40
60
80
100
120
Index

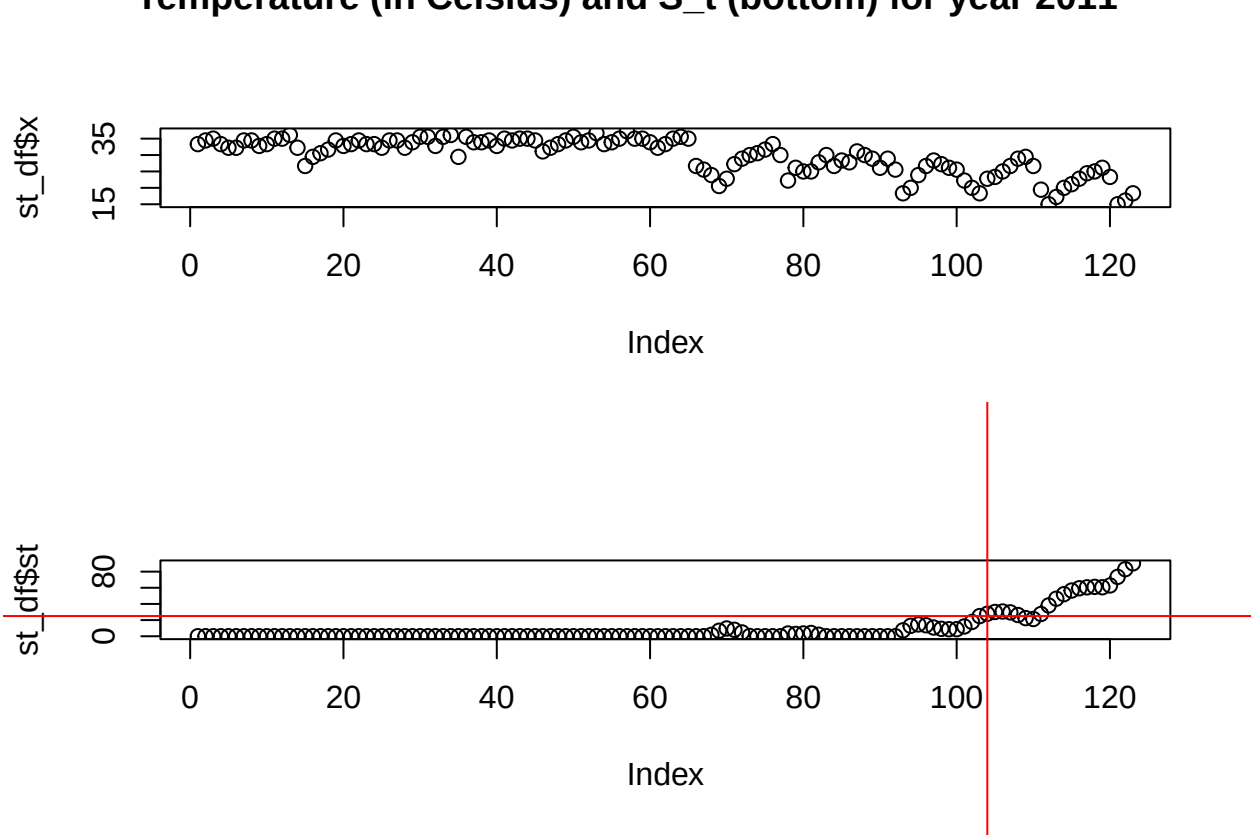

Temperature (in Celsius) and S_t (bottom) for year 2006
st_df$x
15
0
20
40
60
80
100
120
Index
st_df$st
0
80
0
20
40
60
80
100
120
Index

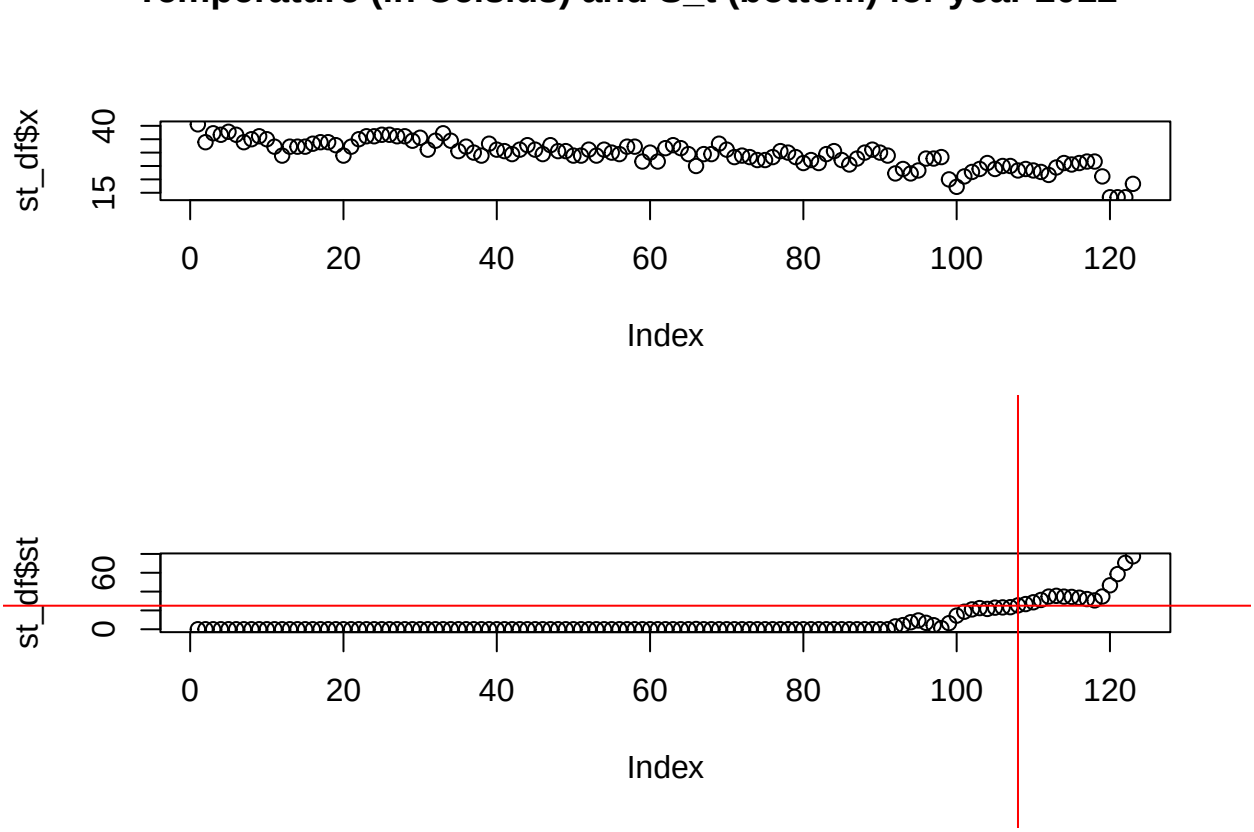

Temperature (in Celsius) and S_t (bottom) for year 2007
st_df$x
15
40
0
20
40
60
80
100
120
Index
st_df$st
0
60
0
20
40
60
80
100
120
Index

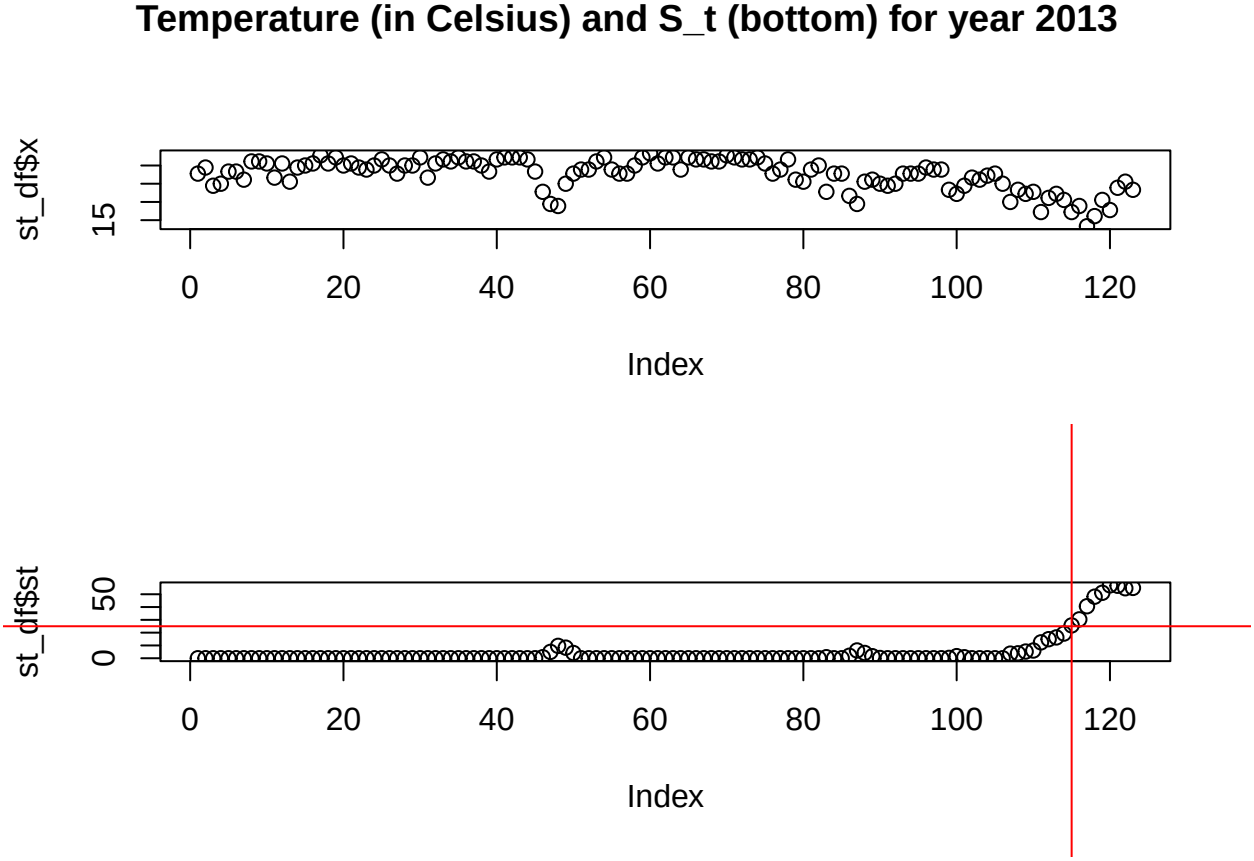

Temperature (in Celsius) and S_t (bottom) for year 2008
st_df$x
10
35
0
20
40
60
80
100
120
Index
st_df$st
0
80
0
20
40
60
80
100
120
Index

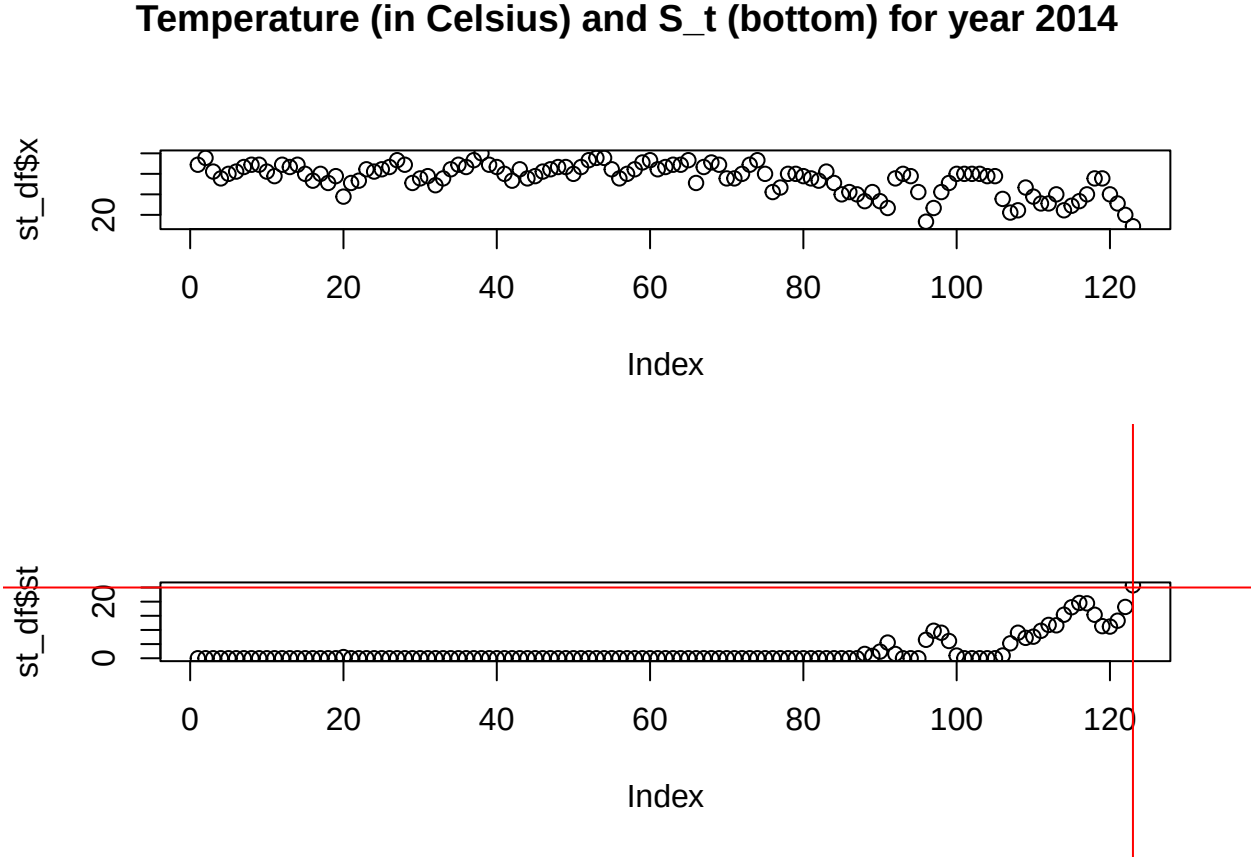

Temperature (in Celsius) and S_t (bottom) for year 2009
st_df$x
10
35
0
20
40
60
80
100
120
Index
st_df$st
0
80
0
20
40
60
80
100
120
Index

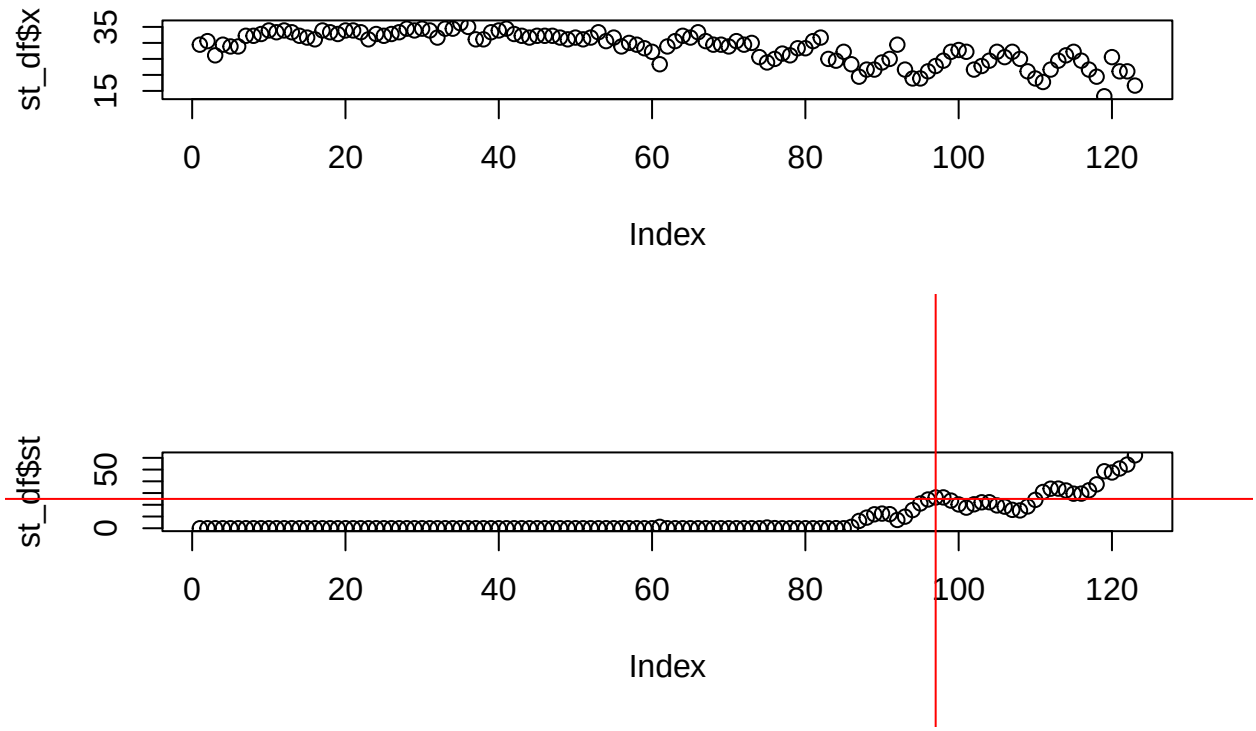

Temperature (in Celsius) and S_t (bottom) for year 2010
st_df$x
20
35
0
20
40
60
80
100
120
Index
st_df$st
0
40
0
20
40
60
80
100
120
Index


Temperature (in Celsius) and S_t (bottom) for year 2011
st_df$x
15
35
0
20
40
60
80
100
120
Index
st_df$st
0
80
0
20
40
60
80
100
120
Index


Temperature (in Celsius) and S_t (bottom) for year 2012
st_df$x
15
40
0
20
40
60
80
100
120
Index
st_df$st
0
60
0
20
40
60
80
100
120
Index


Temperature (in Celsius) and S_t (bottom) for year 2013
st_df$x
15
0
20
40
60
80
100
120
Index
st_df$st
50
0
0
20
40
60
80
100
120
Index


Temperature (in Celsius) and S_t (bottom) for year 2014
st_df$x
20
0
20
40
60
80
100
120
Index
st_df$st
0
20
0
20
40
60
80
100
120
Index




```
change_df <- as.data.frame(do.call(rbind, winter_start_days))
colnames(change_df) = c("year","winter_start","winter_length")
change_df["year_bucket"] = "a.1996_2000"
change_df[change_df$year>=2000,"year_bucket"] = "b.2000_2004"
change_df[change_df$year>=2004,"year_bucket"] = "c.2004_2008"
change_df[change_df$year>=2008,"year_bucket"] = "d.2008_2012"
change_df[change_df$year>=2012,"year_bucket"] = "e.2012_2016"
change_df
```

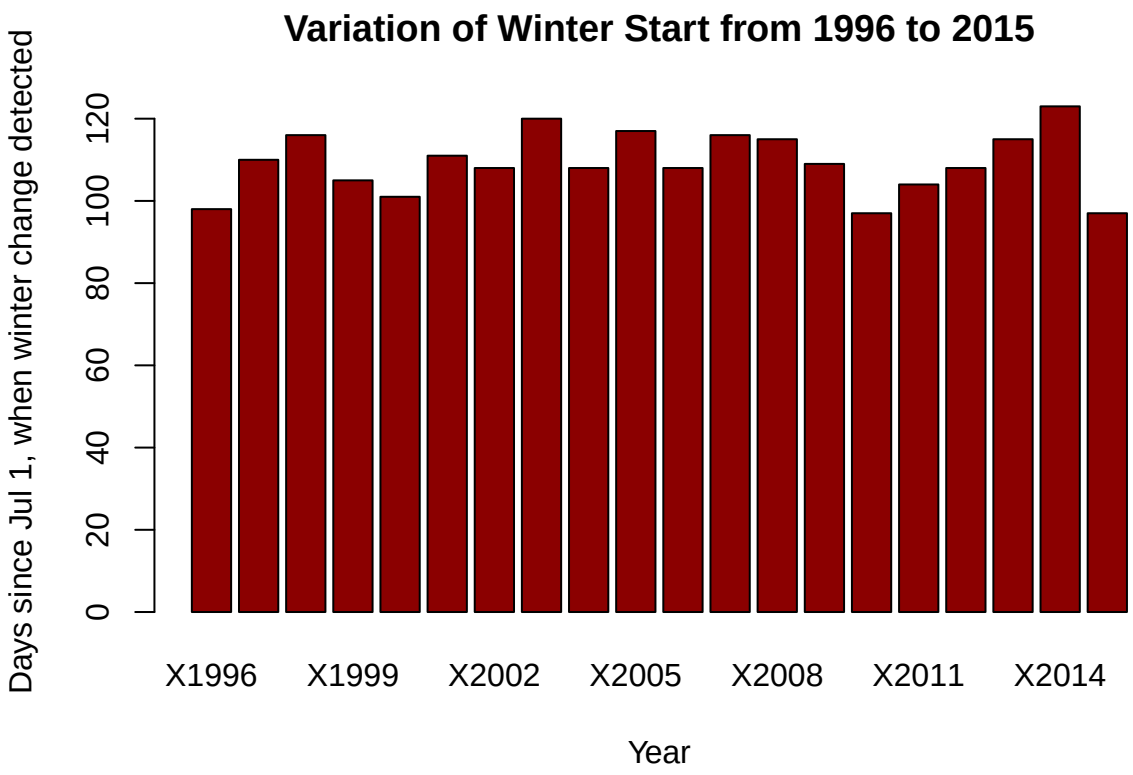
```
##    year winter_start winter_length year_bucket
## 1  1996           98            26 a.1996_2000
## 2  1997          110            14 a.1996_2000
## 3  1998          116             4 a.1996_2000
## 4  1999          105            19 a.1996_2000
## 5  2000          101            23 b.2000_2004
## 6  2001          111             7 b.2000_2004
## 7  2002          108            16 b.2000_2004
## 8  2003          120             4 b.2000_2004
## 9  2004          108            14 c.2004_2008
## 10 2005          117             7 c.2004_2008
## 11 2006          108            16 c.2004_2008
## 12 2007          116             8 c.2004_2008
## 13 2008          115             9 d.2008_2012
## 14 2009          109            15 d.2008_2012
## 15 2010           97            22 d.2008_2012
```

```
## 16 2011          104            18 d.2008_2012
## 17 2012          108            16 e.2012_2016
## 18 2013          115             9 e.2012_2016
## 19 2014          123             1 e.2012_2016
## 20 2015           97            15 e.2012_2016
```

```
aggregate(cbind(winter_start,winter_length) ~ year_bucket, change_df, mean)
```

```
##   year_bucket winter_start winter_length
## 1 a.1996_2000       107.25         15.75
## 2 b.2000_2004       110.00         12.50
## 3 c.2004_2008       112.25         11.25
## 4 d.2008_2012       106.25         16.00
## 5 e.2012_2016       110.75         10.25
```

```
barplot(sapply(winter_start_days,"[[",2),
main = "Variation of Winter Start from 1996 to 2015",
xlab = "Year",
ylab = "Days since Jul 1, when winter change detected",
names.arg = temp_cols,
col = "darkred",
horiz = FALSE)
```



```
plot(sapply(winter_start_days,"[[",1))
axis(1, at=1:length(temp_cols),labels=temp_cols, las=3)
```