Test PMLSeg

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Introduction

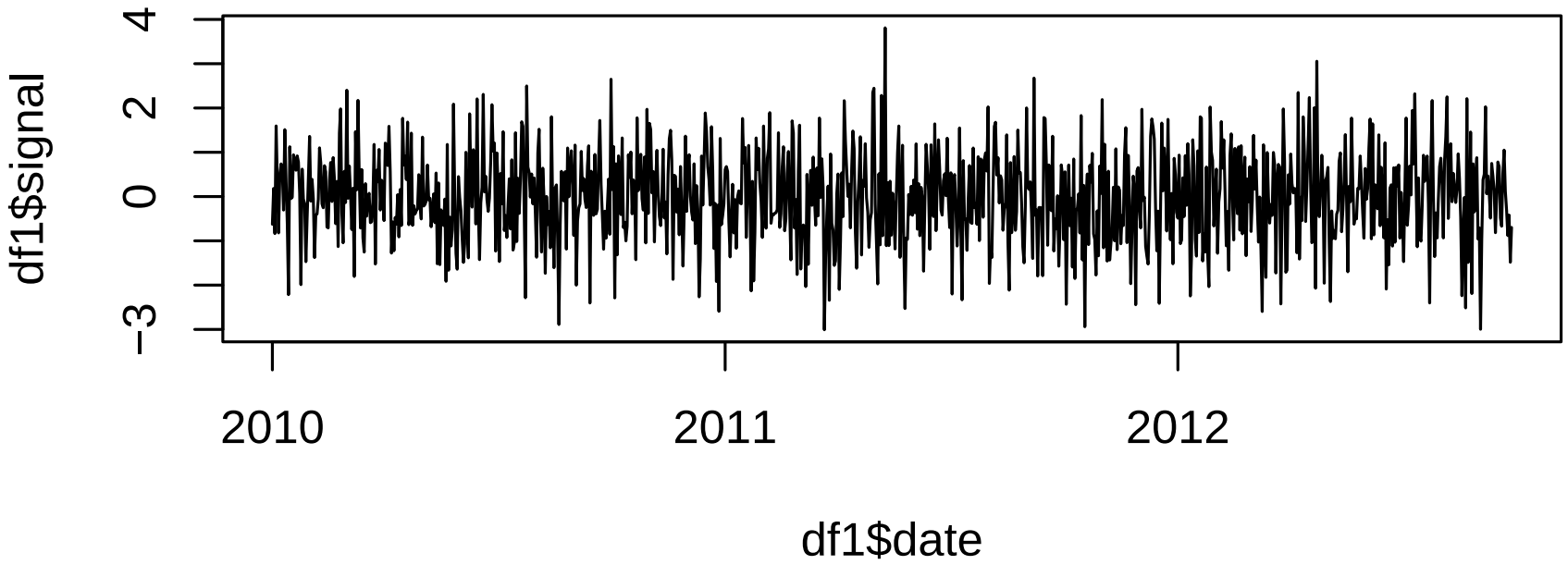
This document presents results from several tests of the PMLSeg package, including:

- Test of the `Segmentation` function with and without offsets, featuring the following examples:
  - Ex1 : zero mean + IID noise
  - Ex2 : periodic mean + IID noise
  - Ex3 : periodic mean + monthly variance
- Tests of other functions such as:
  - `PlotSeg` to visualize segmentation results
  - `Cluster_screening` to detect groups of close change-points (usually due to outliers) and determine whether to keep or remove the cluster. The cluster in this document is determined by a group of close change-points within 80 days.
  - `Validation` to validate the detected change-points with the help of metadata.

Generate Example Data

Ex1 time series

```
set.seed(1)
length_series = 1000
df1 = data.frame(date = seq.Date(from = as.Date("2010-01-01"),
                                 to = as.Date("2010-01-01")+(length_series-1),
                                 by = "day"),
                 signal = rnorm(n = length_series, mean = 0, sd = 1))

plot(df1$date, df1$signal, type = "l")
```

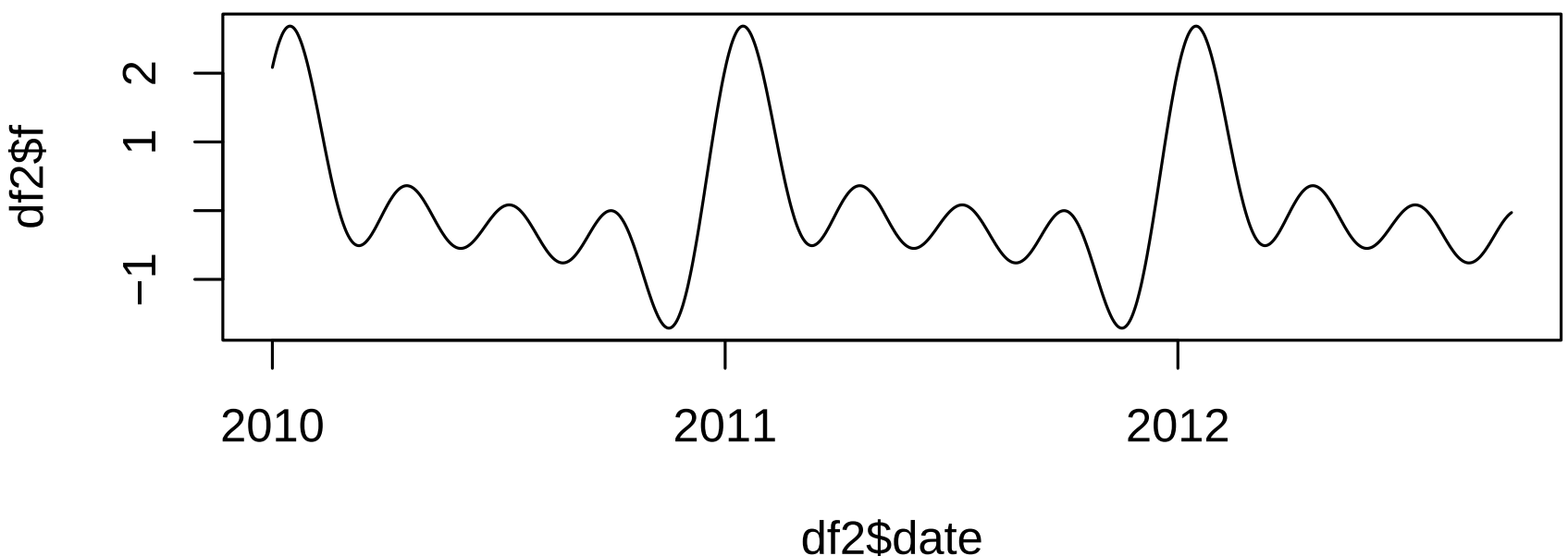



```
head(df1, 3)
#>         date     signal
#> 1 2010-01-01 -0.6264538
#> 2 2010-01-02  0.1836433
#> 3 2010-01-03 -0.8356286
```

Generate Example Data

Ex2 time series : Add the functional with 4 Fourier series components, each with a coefficient of 0.5

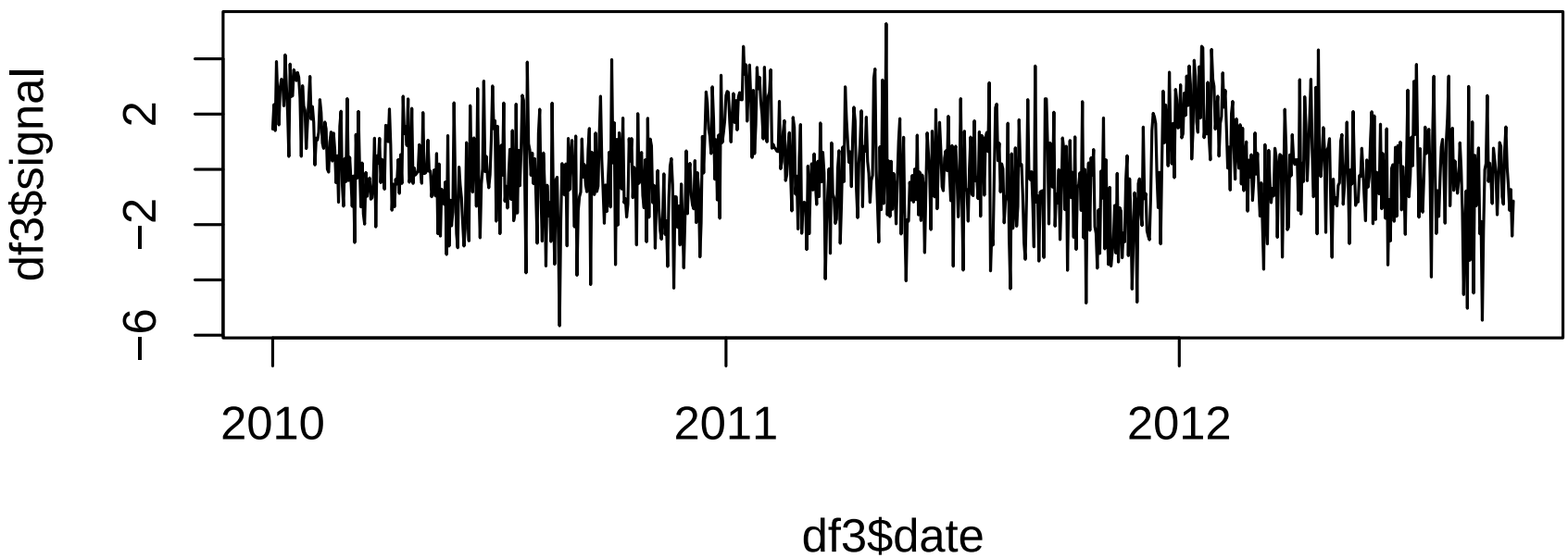
```
library(dplyr)

T <- 365.25
df2 <- df1 %>%
  mutate(t = as.numeric(date - date[1])+1,
  f = rowSums(sapply(1:4, function(i) 0.5*cos(i*t*(2*pi)/T) + 0.5*sin(i*t*(2*pi)/T))),
  signal = signal + f)

head(df2, 3)
#>         date   signal t        f
#> 1 2010-01-01 1.457297 1 2.083751
#> 2 2010-01-02 2.346461 2 2.162818
#> 3 2010-01-03 1.401342 3 2.236970
plot(df2$date, df2$f, type = "l")
```



Generate Example Data

Ex3 time series : Apply the same functional as Ex2, adjusted for monthly variance

```
std = c(1, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.6, 1.5, 1.4, 1.3)

df3 <- df1 %>%
  mutate(sd = std[as.numeric(format(date, "%m"))],
         signal = signal * sd ) %>%
  mutate(signal = signal + df2$f)

head(df3, 3)
#>         date   signal sd
#> 1 2010-01-01 1.457297  1
#> 2 2010-01-02 2.346461  1
#> 3 2010-01-03 1.401342  1
plot(df3$date, df3$signal, type = "l")
```



Generate Example Data

Harmonize Formats of 3 Dataframes for Testing

```
df2 <- df2 %>% select(date, signal)
df3 <- df3 %>% select(date, signal)

names(df1)
#> [1] "date"   "signal"
names(df2)
#> [1] "date"   "signal"
names(df3)
#> [1] "date"   "signal"
```

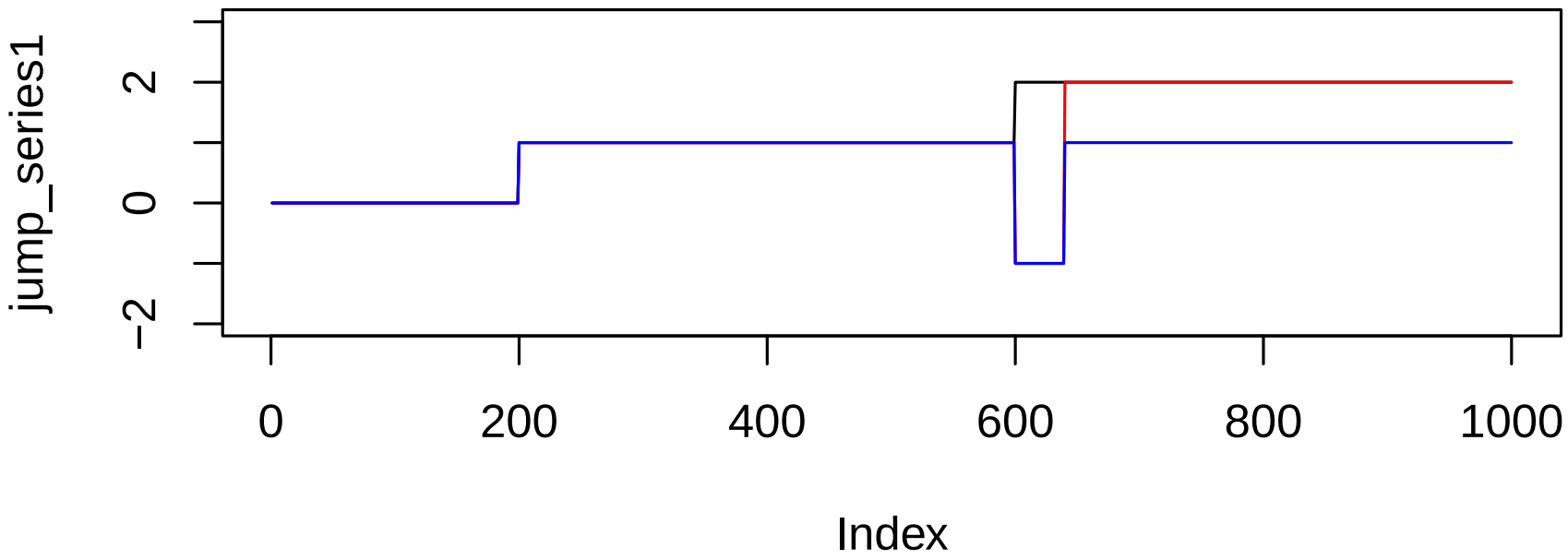
Preliminary Settings

Generate different offset series to add to the original series :

```r
# Function to generate jump series
generate_jump_series <- function(jump_indices, jump_amp, length_series) {
  jump_series <- rep(0, length_series)
  jump_indices <- c(1, jump_indices, length_series + 1)

  changes <- rep(0, length_series)
  changes[jump_indices[-length(jump_indices)]] <- jump_amp

  jump_series <- cumsum(changes)

  return(jump_series)
}
# No cluster
jump_ind1 <- c(200, 600)
jump_amp1 <- c(0, 1, 1)
# One cluster formed by the second and third change-points, which need to be replace by the
jump_ind2 <- c(200, 600, 640)
jump_amp2 <- c(0, 1, -2, 3)
# One cluster formed by the second and third change-points, which need to be removed
jump_amp3 <- c(0, 1, -2, 2)
```

Premilinary setting

```r
# Generate jump series
jump_series1 <- generate_jump_series(jump_ind1, jump_amp1, length_series)
jump_series2 <- generate_jump_series(jump_ind2, jump_amp2, length_series)
jump_series3 <- generate_jump_series(jump_ind2, jump_amp3, length_series)
plot(jump_series1, type = "l", ylim = c(-2,3))
lines(jump_series2, col = "red")
lines(jump_series3, col = "blue")
```



Testing the Segmentation Function

When the series is homogeneous

```
library(PMLseg)
# Ex1
seg1a = Segmentation(OneSeries = df1, FunctPart = FALSE)
str(seg1a)
#> List of 5
#>  $ Tmu     :'data.frame':    1 obs. of  5 variables:
#>   ..$ begin: int 1
#>   ..$ end  : int 1000
#>   ..$ mean : num -0.00423
#>   ..$ se   : num 29.7
#>   ..$ np   : num 1000
#>  $ FitF    : logi FALSE
#>  $ CoeffF  : logi FALSE
#>  $ MonthVar: num [1:12] 1.089 0.887 1.334 1.092 1.21 ...
#>  $ SSR     : num 933
seg1a$Tmu
#>   begin  end          mean       se   np
#> 1     1 1000 -0.004229094 29.73496 1000
```

No change-points are detected, as shown in the `Tmu` dataframe, which lists all segments of the series. The mean is close to 0. Additionally, the results include not only the `Tmu` dataframe but also other outputs such as the fitted functional part `FitF` (which is not fitted when `FunctPart` is set to FALSE), coefficients of functional elements `CoeefF`, monthly variance `MonthVar`, and the Sum of Squares of Residuals `SSR`.

Test the Segmentation Function

When series is homogeneous for Example 2 and 3

```
# Ex2
seg2a = Segmentation(OneSeries = df2, FunctPart = TRUE)
seg2a$Tmu
#>   begin  end          mean       se   np
#> 1     1 1000 -0.007048795 29.70068 1000
# Ex3
seg3a = Segmentation(OneSeries = df3, FunctPart = TRUE)
seg3a$Tmu
#>   begin  end         mean       se   np
#> 1     1 1000 -0.01231815 22.51285 1000
```

No change-points are detected in these two examples either.

Test the Segmentation Function

Adding Jump Series to the original Series

```
# Ex1
df1b <- df1 %>% mutate(signal = signal + jump_series1)
seg1b = Segmentation(OneSeries = df1b, FunctPart = FALSE)
seg1b$Tmu
#>   begin  end       mean       se  np
#> 1     1  199 0.04231954 13.32685 199
#> 2   200  598 0.99732352 18.65043 399
#> 3   599 1000 1.96897996 18.96817 402

# Ex2
df2b <- df2 %>% mutate(signal = signal + jump_series1)
seg2b = Segmentation(OneSeries = df2b, FunctPart = TRUE)
seg2b$Tmu
#>   begin  end       mean       se  np
#> 1     1  200 0.02694284 13.37988 200
#> 2   201  598 0.99309421 18.60675 398
#> 3   599 1000 1.97809762 18.93598 402

# Ex3
df3b <- df3 %>% mutate(signal = signal + jump_series1)
seg3b = Segmentation(OneSeries = df3b, FunctPart = TRUE)
seg3b$Tmu
#>   begin  end       mean       se  np
#> 1     1  200 0.03770921 10.89491 200
#> 2   201  598 0.98628411 13.83300 398
#> 3   599 1000 1.96699190 14.04261 402
```

Test the Segmentation Function

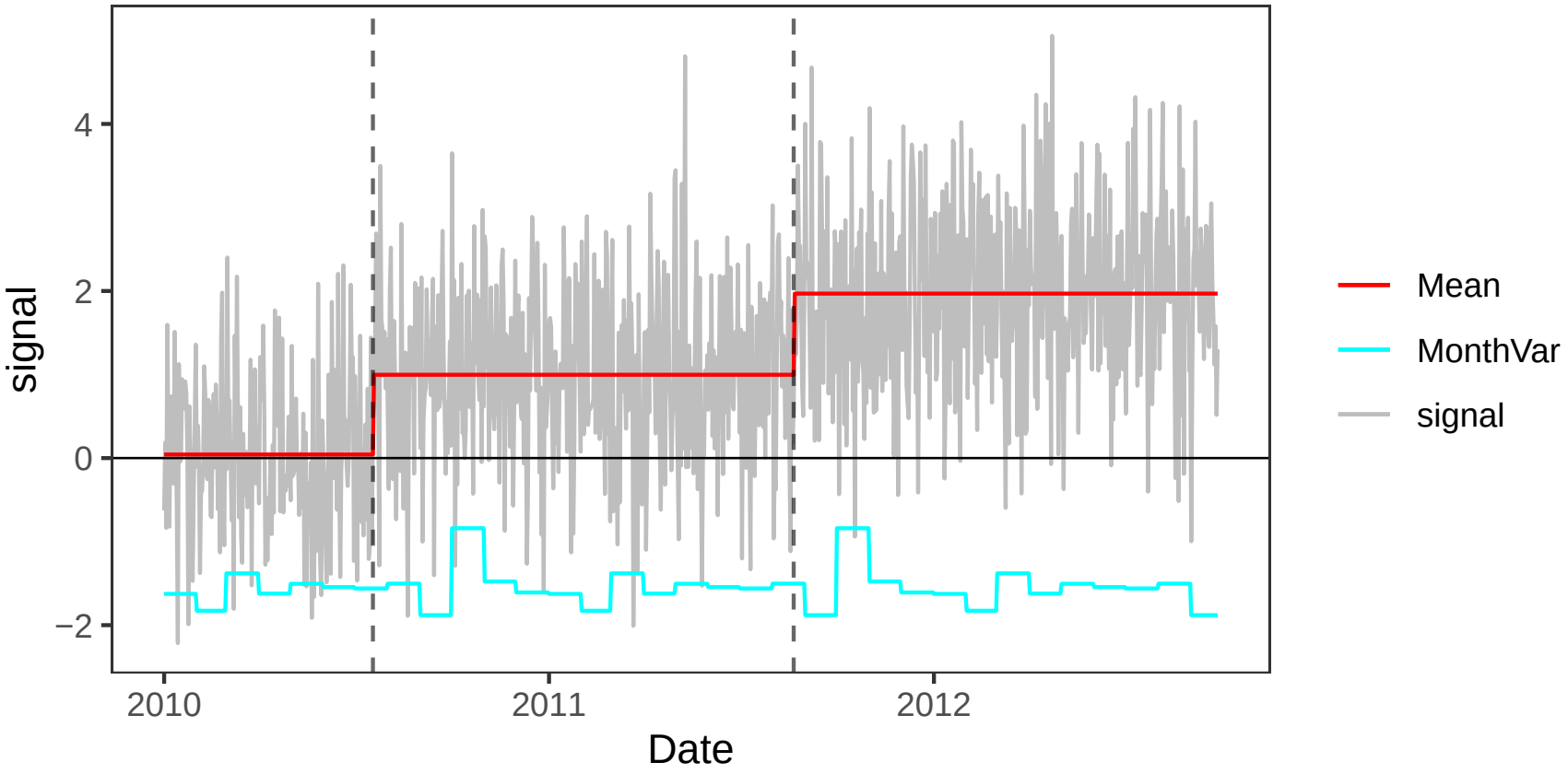
Adding other jump series in the most complicated series (Ex3)

```
df3c <- df3 %>% mutate(signal = signal + jump_series2)
seg3c = Segmentation(OneSeries = df3c, FunctPart = TRUE)
seg3c$Tmu
#>   begin  end        mean        se  np
#> 1     1  200  0.03375487 10.894914 200
#> 2   201  599  0.98739329 13.812429 399
#> 3   600  639 -0.92931430  4.076796  40
#> 4   640 1000  1.95834904 13.400214 361

df3d <- df3 %>% mutate(signal = signal + jump_series3)
seg3d = Segmentation(OneSeries = df3d, FunctPart = TRUE)
seg3d$Tmu
#>   begin  end        mean        se  np
#> 1     1  200  0.03603943 10.894914 200
#> 2   201  599  0.98892940 13.817528 399
#> 3   600  641 -0.92136663  4.133638  42
#> 4   642 1000  0.96240352 13.388052 359
```

Test the PlotSeg Function

Visualize the segmentation result of example 1

```
PlotSeg(OneSeries = df1b, SegRes = seg1b, FunctPart = FALSE)
```



Test the PlotSeg Function

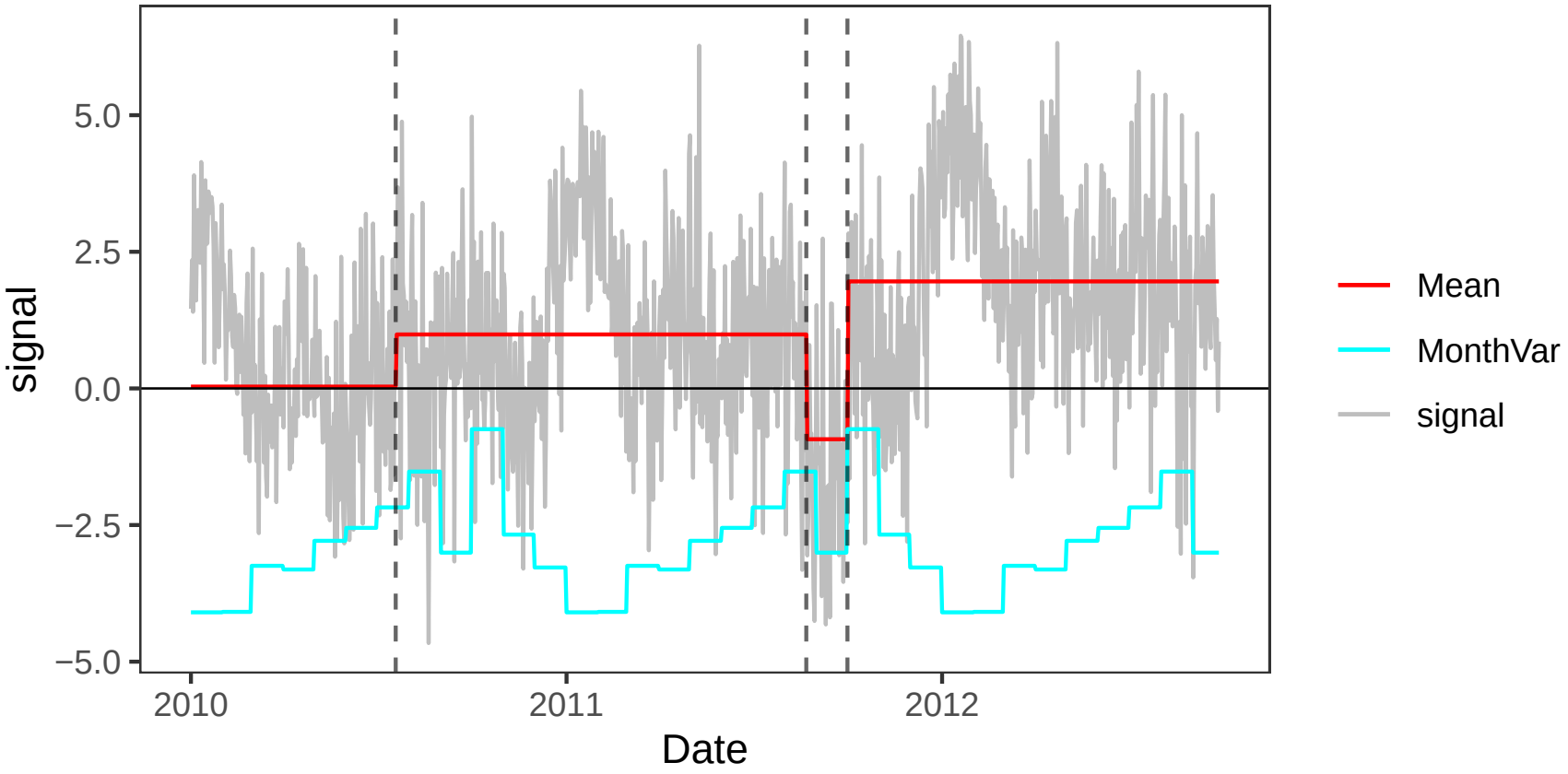
Visualize the segmentation result of example 2

```
PlotSeg(OneSeries = df2b, SegRes = seg2b, FunctPart = FALSE)
```

Test the PlotSeg Function

Visualize the segmentation result of example 3 with another jump series

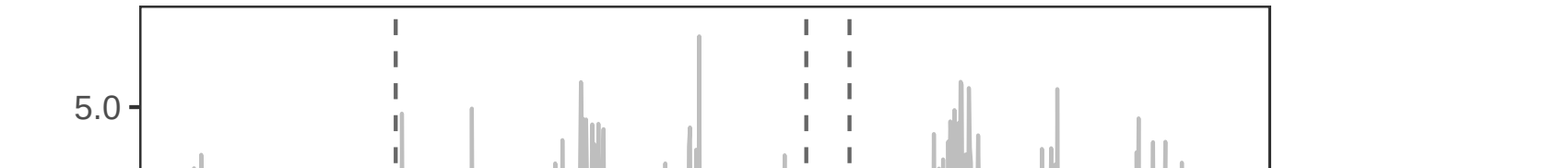
```
PlotSeg(OneSeries = df3c, SegRes = seg3c, FunctPart = FALSE)
```



Test the PlotSeg Function

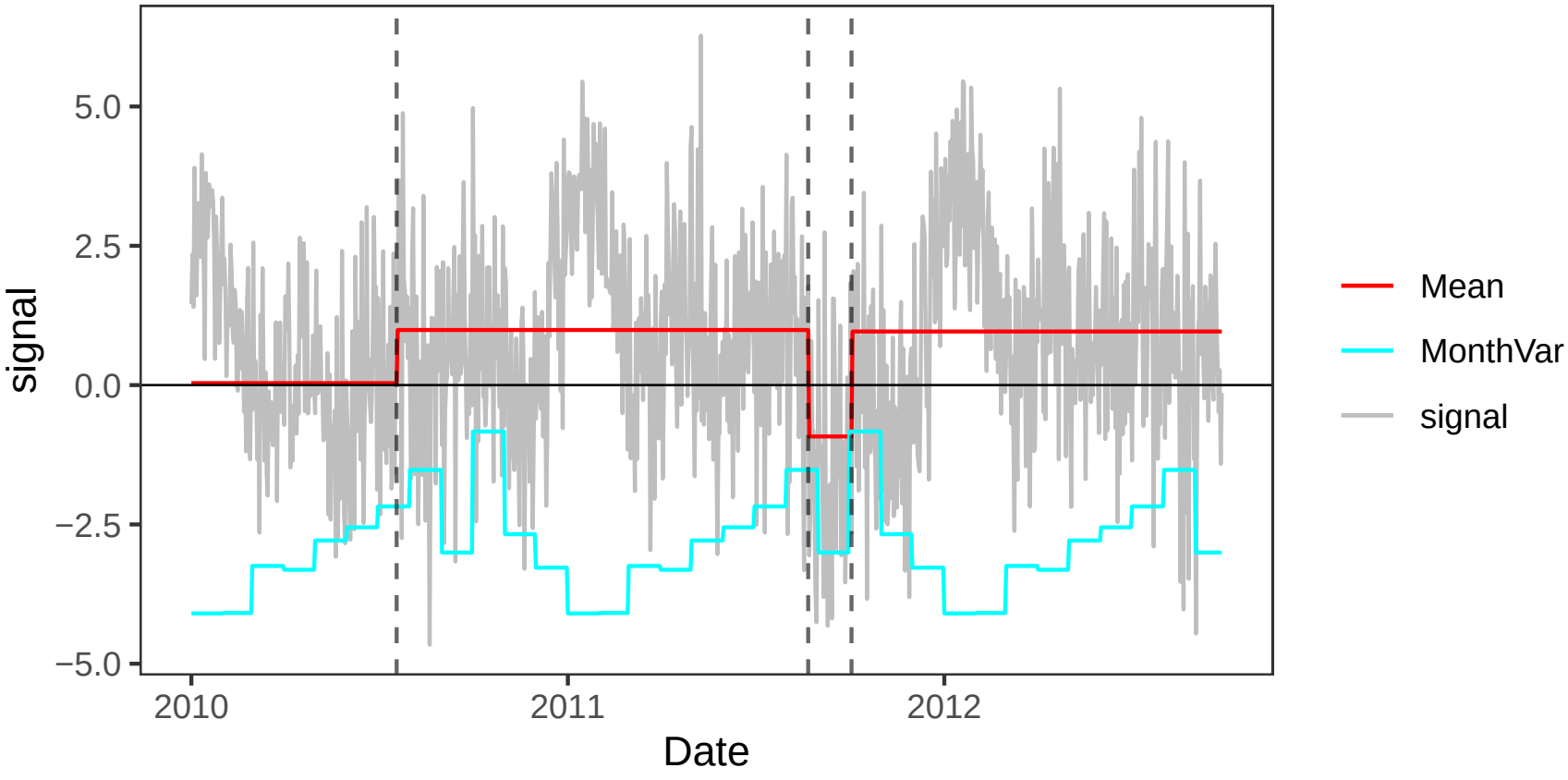
Visualize the segmentation result of example 3 with another jump series

```
PlotSeg(OneSeries = df3d, SegRes = seg3d, FunctPart = FALSE)
```



Test the PlotSeg Function

```
PlotSeg(OneSeries = df3d, SegRes = seg3d, FunctPart = FALSE)
```



Test the Cluster_screening Function

Segmentation sometime detects very short segment like in example 3c, 3d. When it is too close and after cluster, the change in mean is not significant, we will remove such kind of cluster. If it is significant, we will replace a cluster by the middle point and remove the data inside the cluster.

```
# Validate the segmentation result wrt metadata
screening1 = Cluster_screening(Tmu = seg3c$Tmu,
                               MaxDist = 80)
screening1
#> $UpdatedCP
#> [1]  200  620 1000
#>
#> $RemoveData
#>   begin end
#> 1   600 639
#>
#> $ChangeCP
#> [1] "Yes"

screening2 = Cluster_screening(Tmu = seg3d$Tmu,
                               MaxDist = 80)
screening2
#> $UpdatedCP
#> [1]  200 1000
#>
#> $RemoveData
#>   begin end
#> 1   600 641
#>
#> $ChangeCP
#> [1] "Yes"
```

Test the UpdatedParametersForFixedCP function

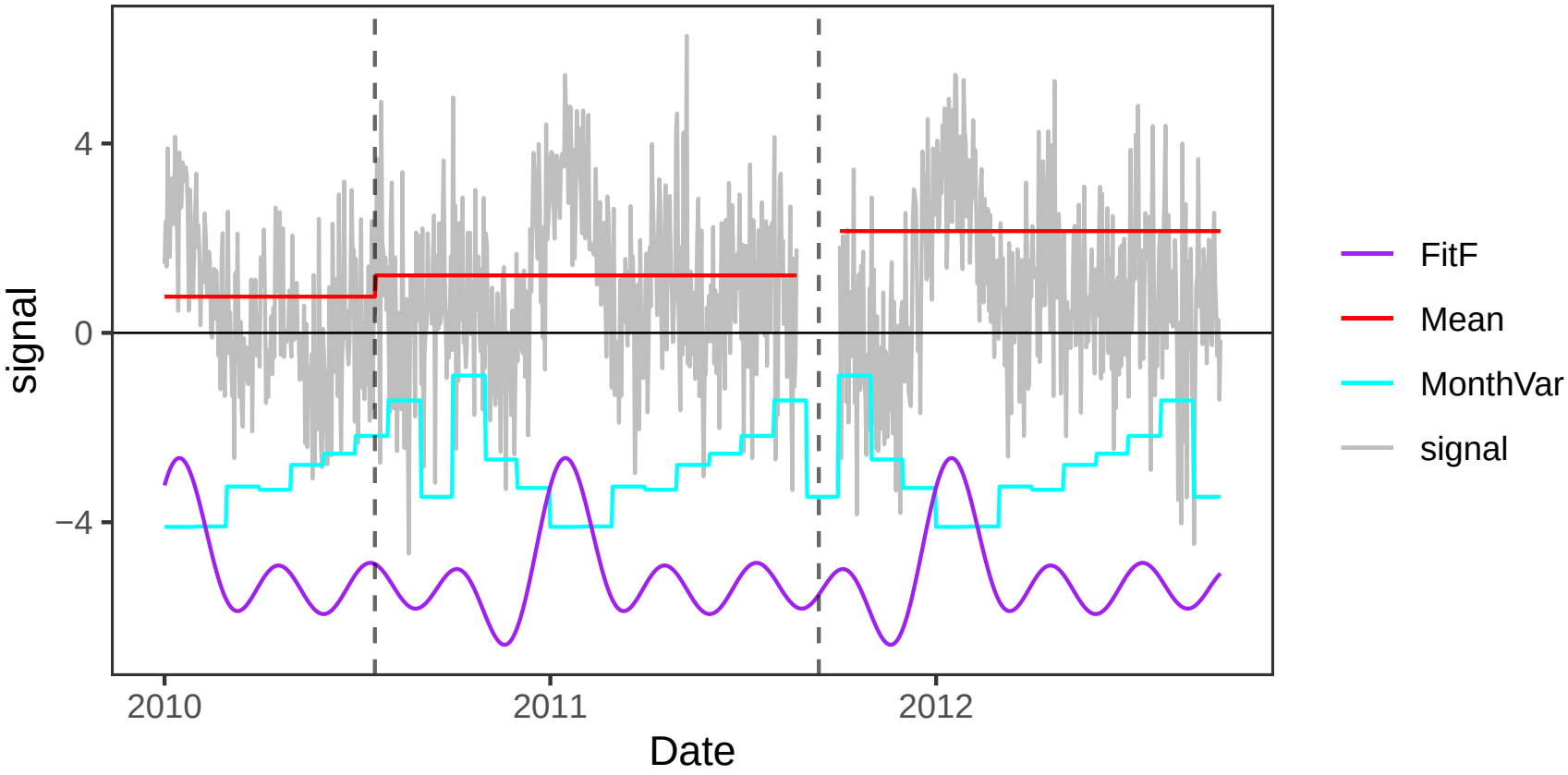
When the screening say it is needed to replace the changepoint, we need to update the Tmu dataframe.

```
# Validate the segmentation result wrt metadata
seg_upd = UpdatedParametersForFixedCP(OneSeries = df3c,
                                      ResScreening = screening1)
str(seg_upd)
#> List of 4
#>  $ MonthVar: num [1:12] 1.06 1.07 1.91 1.85 2.37 ...
#>  $ Tmu     :'data.frame':    3 obs. of  5 variables:
#>   ..$ begin: num [1:3] 1 201 621
#>   ..$ end  : num [1:3] 200 620 1000
#>   ..$ mean : num [1:3] 0.765 1.213 2.149
#>   ..$ se   : num [1:3] 10.9 14.3 13.9
#>   ..$ np   : num [1:3] 200 420 380
#>  $ FitF    : Named num [1:1000] 1.94 2.02 2.09 2.15 2.21 ...
#>   ..- attr(*, "names")= chr [1:1000] "1" "2" "3" "4" ...
#>  $ CoeffF  : Named num [1:8] 0.469 0.268 0.483 0.472 0.418 ...
#>   ..- attr(*, "names")= chr [1:8] "cos1" "sin1" "cos2" "sin2" ...
seg_upd$Tmu
#>   begin  end      mean       se  np
#> 1     1  200 0.7653757 10.89491 200
#> 2   201  620 1.2131500 14.27907 420
#> 3   621 1000 2.1493934 13.91676 380
```

Test the UpdatedParametersForFixedCP function

Visualize the time series after the update segmentation

```
PlotSeg(OneSeries = df3d,
        SegRes = seg_upd,
        RemoveData = screening1$RemoveData)
```



Compare to the result before the cluster screening

```
PlotSeg(OneSeries = df3d,
        SegRes = seg3d)
```

Test the Validation function

Validate the detected change-points with respect to the metadata

```
# Create a metadata for example
meta = data.frame(date = df1$date[jump_ind2],
                  type = c("type1", "type2", "type3"))
meta
#>         date  type
#> 1 2010-07-19 type1
#> 2 2011-08-23 type2
#> 3 2011-10-02 type3

# Validate the segmentation result wrt metadata
Validation(OneSeries = df3d,
           Tmu = seg_upd$Tmu,
           MinDist = 62,
           Metadata = meta)
#> # A tibble: 2 x 5
#>   CP         closestMetadata Distance type  valid
#>   <date>     <date>             <dbl> <chr> <dbl>
#> 1 2010-07-19 2010-07-19             0 type1     1
#> 2 2011-09-12 2011-08-23            20 type2     1
```

Visualize results with metadata

```
PlotSeg(OneSeries = df3d,
        SegRes = seg_upd,
        RemoveData = screening1$RemoveData,
        Metadata = meta)
```