CSIRO Mathematical and Information Sciences

Statistical Modelling for Trends in Groundwater level in Towerrinning

Prepared for Agriculture Western Australia

As Part of a National Land and Water Resources Audit Project

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1. Introduction

The National Land and Water Resources Audit Project intended to use Towerrinning area in testing potential Salinity models using the changes of groundwater level as a predictor.

There are hundreds of bores monitored in this area. The potentially useful bores were selected by Mr. Don Bennet of AgWA Bunbury. Dr. Quanxi Shao and Geoff Hodgson were assigned to fit the trends in groundwater level using the constraint threshold regression developed by CSIRO Mathematical and Information Sciences; see Shao (1999) and Shao et al (1999) for detailed technical descriptions.

The computing program was written in S+ by Dr Shao. All the outputs were from S+ software. There are 149 bores selected. Shao worked on the first 93 bores and Hodgson on the rest 56.

The Model fits are given in Section 2. The Excel table and text file can be obtained from the authors.

2. Models for individual bores

(1). CK01D: There are 40 observations. The final model is

$$x_t = \begin{cases} -1.5188 - 0.0933t - 0.3117\sin(2\pi t) & \text{if} \quad t \le 36.4411 \\ 18.9321 - 0.6159t - 0.3592\sin(2\pi t) & \text{if} \quad t > 36.4411 \end{cases}$$

where the break point was at 02/07/1996. The estimated rates of decrease were 9.33cm/year and 61.59cm/year respectively. The size of jump was 133.22cm. The simple linear regression is

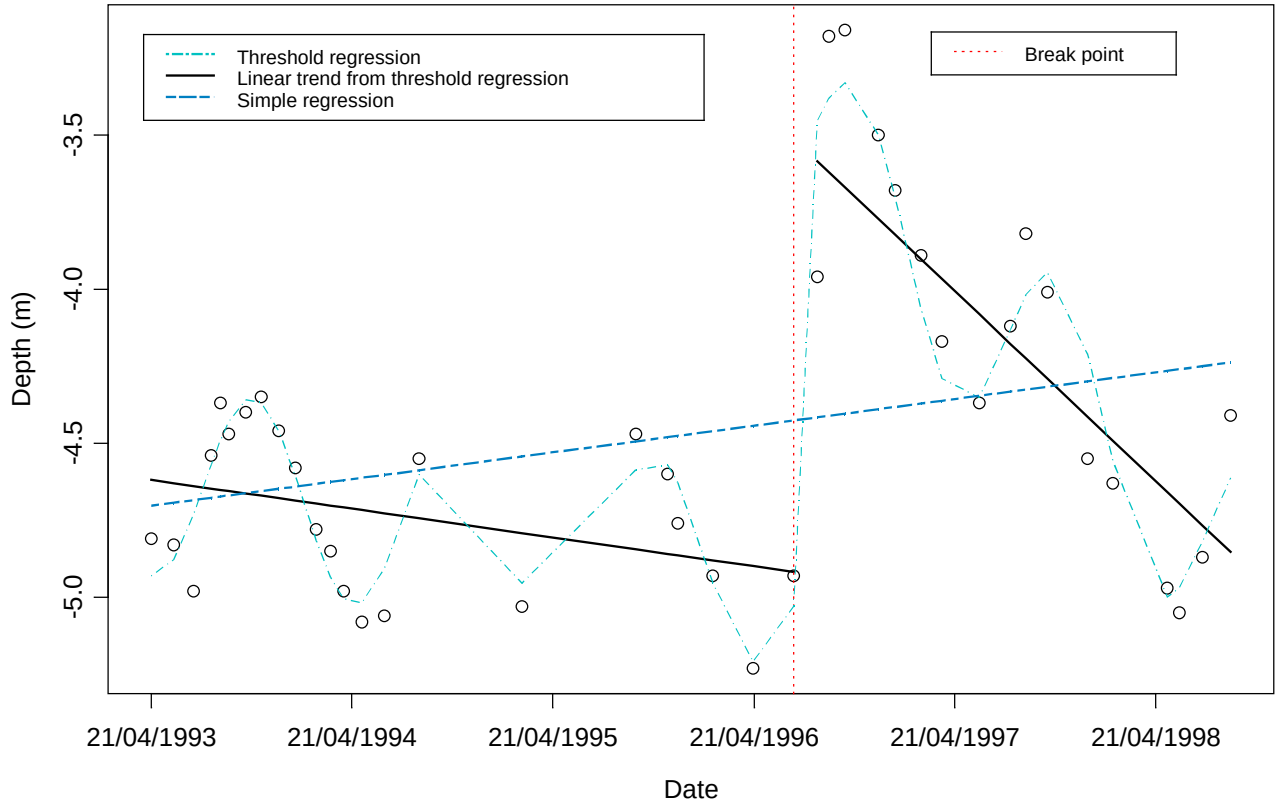
$$x_t = -1.5188 + 0.0865t,$$

giving an estimated rate of increase of 8.65cm/year.

A part of S+ output is the following.

```
input break dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A break date is a date at which all the trend changes)
1: 02/07/1996
2:
by= 36.441095890411

                   Value Std. Error  t value Pr(>|t|)
    (Intercept)  -1.5188   0.6908    -2.1985   0.0398
        slope.1  -0.0933   0.0200    -4.6563   0.0002
amplitude.sin.1  -0.3117   0.0283   -11.0236   0.0000
Corrected AIC for this segment=  -3.37233938488667

                   Value Std. Error  t value Pr(>|t|)
```

```
    (Intercept)  18.9321   2.9650     6.3852   0.0000
        slope.1  -0.6159   0.0789    -7.8017   0.0000
amplitude.sin.1  -0.3592   0.0806    -4.4579   0.0005
Corrected AIC for this segment=  -1.70348562347612
-4.91741607372142-(-3.58524307988301)
[1] -1.332173

Overall Corrected AIC=-2.51187629663006

              Value Std. Error t value Pr(>|t|)
(Intercept) -7.5790  1.6237    -4.6677  0.0000
sample.year  0.0865  0.0453     1.9080  0.0640
Corrected AIC for simple linear regression=-0.249836017781313
```



(2) CK03D

There are 40 observations. The optimal model is given by

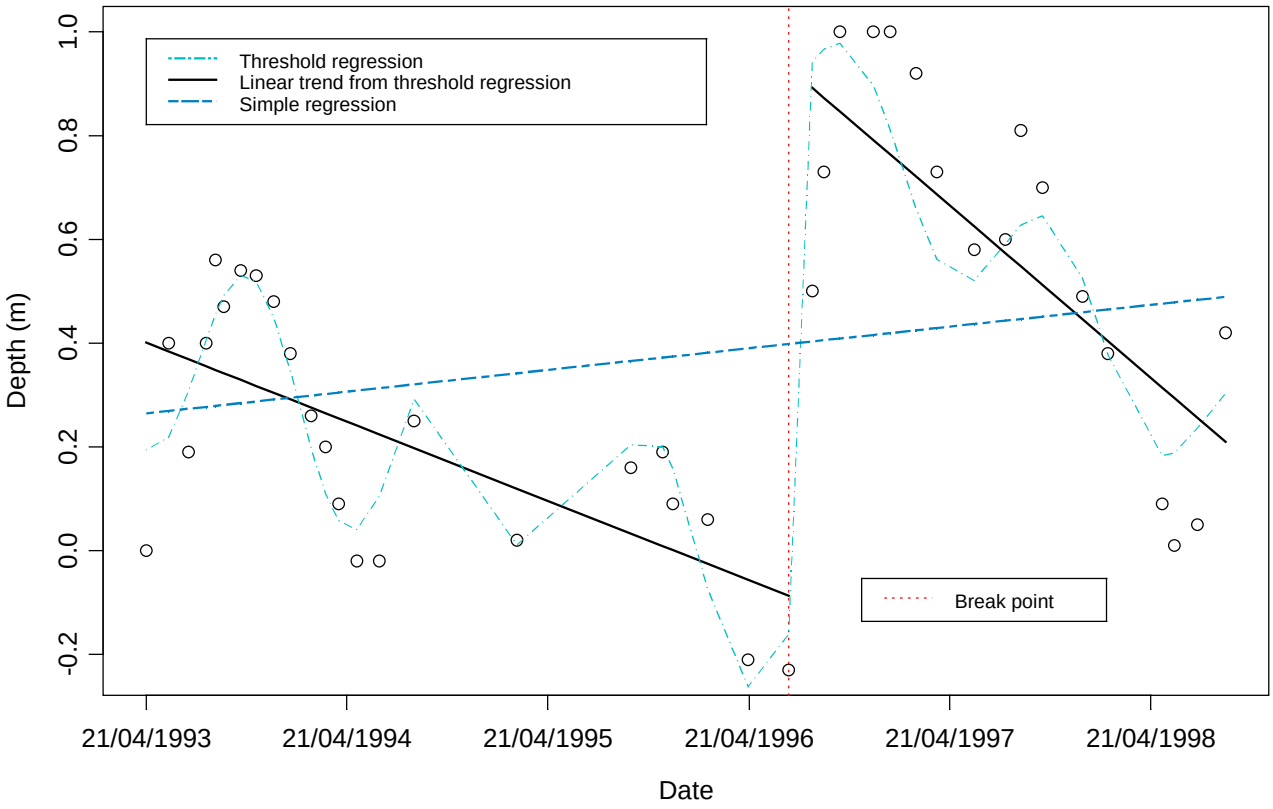
$$x_t = \begin{cases} 5.4681 - 0.1524t - 0.2072\sin(2\pi t) & \text{if} \quad t \le 36.4411 \\ 13.0130 - 0.3315t - 0.1309\sin(2\pi t) & \text{if} \quad t > 36.4411 \end{cases}$$

where the break point was at 02/07/1996. The estimated rates of decrease were 15.24cm/year and 33.15cm/year respectively. The size of jump was 97.89cm. The simple linear regression is

$$x_t = -1.1242 + 0.0418t,$$

giving an estimated rate of increase of 4.18cm/year. A part of S+ output is below.

```
input break dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A break date is a date at which all the trend changes)
1: 02/07/1996
2:
by= 36.441095890411

Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept)  5.4681  0.6502     8.4104  0.0000
        slope.1 -0.1524  0.0189    -8.0867  0.0000
amplitude.sin.1 -0.2072  0.0266    -7.7832  0.0000
Corrected AIC for this segment=  -3.49366507256723

Coefficients:
                   Value Std. Error  t value Pr(>|t|)
    (Intercept)  13.0130   2.8084     4.6337   0.0004
        slope.1  -0.3315   0.0748    -4.4339   0.0006
amplitude.sin.1  -0.1390   0.0763    -1.8208   0.0901
Corrected AIC for this segment=  -1.81204427467546

Overall Corrected AIC=-2.62350357718839

-0.0868585183675661-(0.891995652199096)
[1] -0.9788542


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -1.1242  1.0659    -1.0546  0.2982
sample.year  0.0418  0.0298     1.4034  0.1686
Corrected AIC for simple linear regression=-1.091607512468
```


Threshold regression
Linear trend from threshold regression
Simple regression
Break point
Depth (m)
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
21/04/1993
21/04/1994
21/04/1995
21/04/1996
21/04/1997
21/04/1998
Date

(3) CK04D

There are 40 observations. The final model is given by

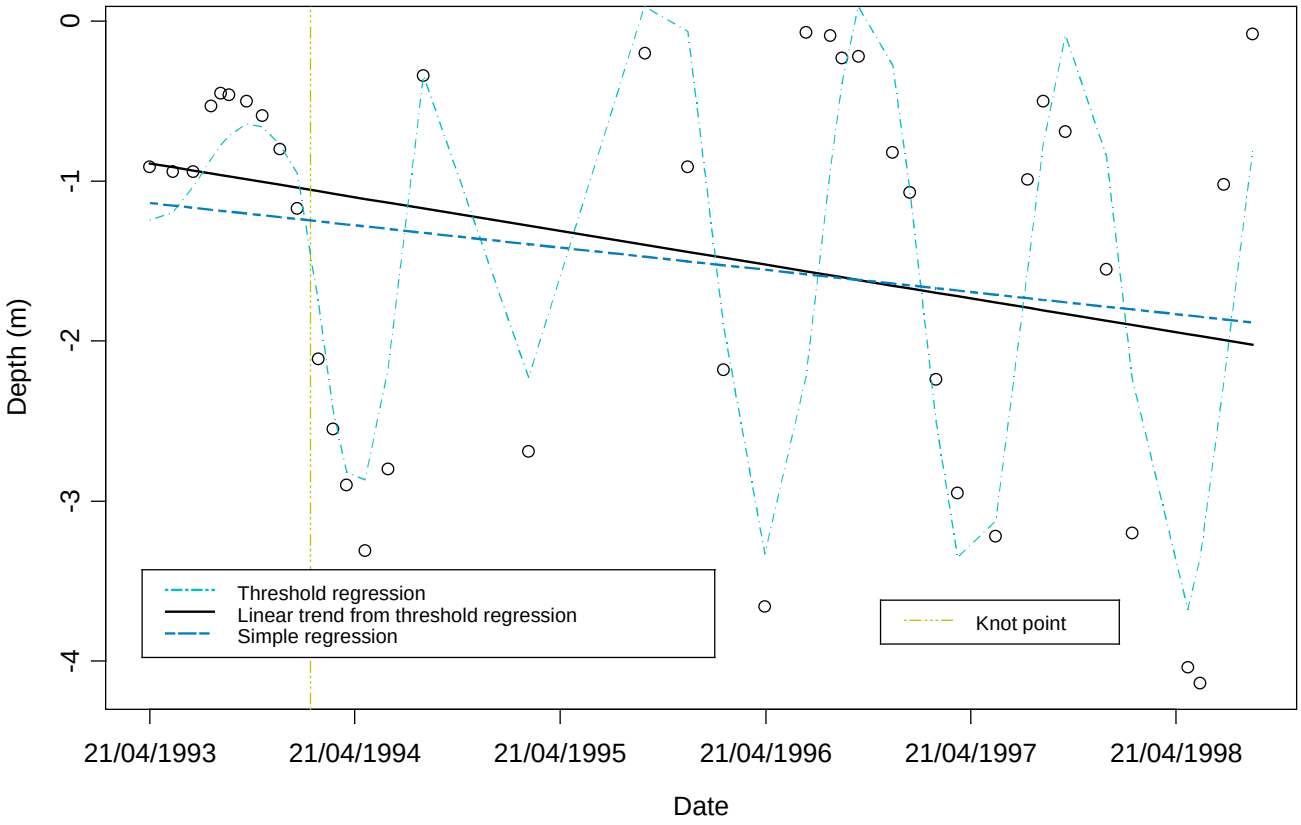
$$x_t = 6.1207 - 0.2109\,t - 0.3556\sin(2\pi t) - 1.4611\,\delta_{(t-34.0247)}\sin(2\pi t)$$

where the knot point was at 01/02/1994. The estimated rate of decrease was 21.09cm/year. The simple linear regression is

$$x_t = 3.4801 - 0.1389\,t$$

giving an estimated rate of decrease of 13.89cm/year. A part of S+ output is below.

```
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/02/1994
2:
ky= 34.0246575342466

Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept)  6.1207  2.0676     2.9603  0.0055
        slope.1 -0.2109  0.0576    -3.6591  0.0008
amplitude.sin.1 -0.3556  0.2847    -1.2494  0.2198
amplitude.sin.2 -1.4611  0.3388    -4.3126  0.0001

Overall Corrected AIC=0.238550966288497

Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  3.4801  4.0226     0.8651  0.3925
sample.year -0.1389  0.1123    -1.2367  0.2240
Corrected AIC for simple linear regression=1.56862767143718
```


Depth (m)
0
-1
-2
-3
-4
21/04/1993
21/04/1994
21/04/1995
21/04/1996
21/04/1997
21/04/1998
Date
Threshold regression
Linear trend from threshold regression
Simple regression
Knot point

(4) CK05I.

There are 40 observations. In the original data file, The depth at 15/Feb/1994 is extremely large. After Don checked the original sheet, we recognised there was an input error. The true value should be 0.2 rather than 0.8. The optimal model is given by

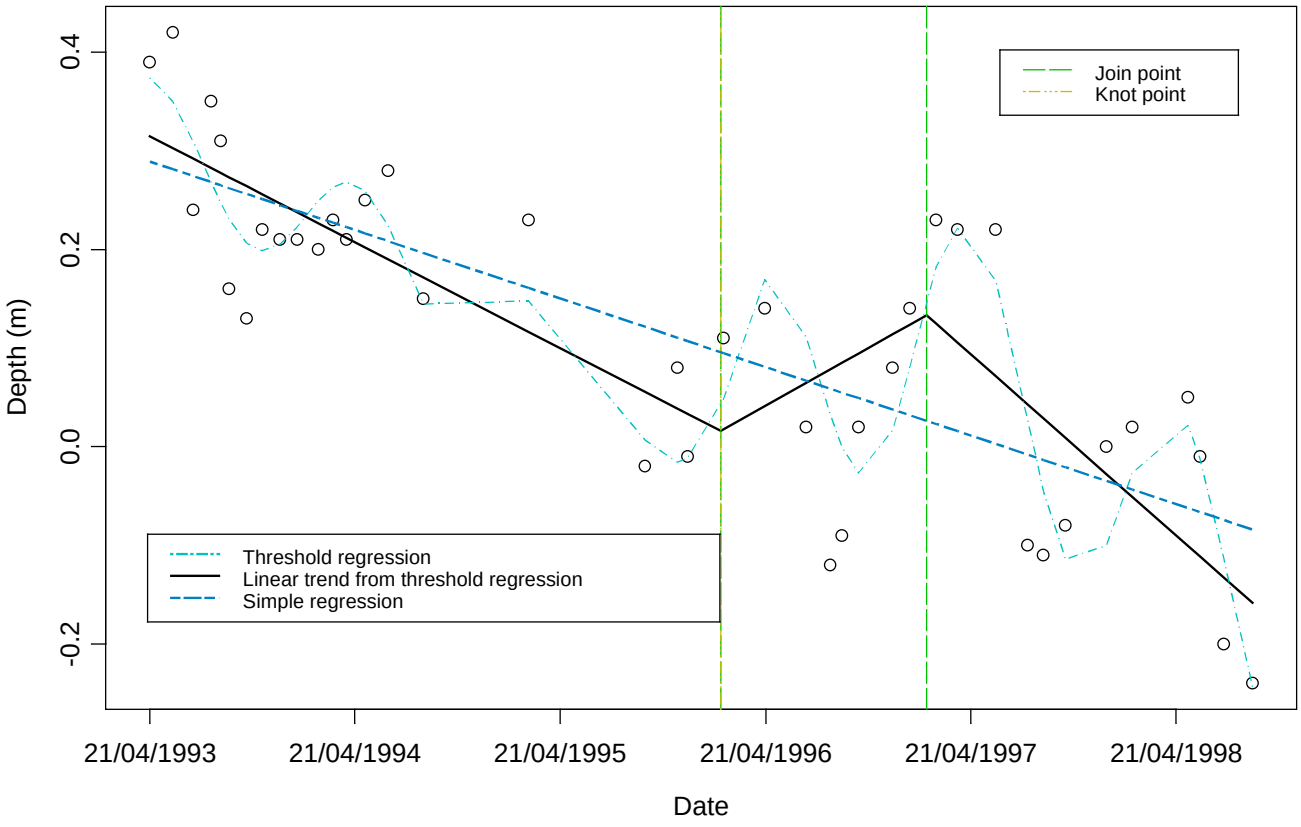
$$x_t = 3.8829 - 0.1073t + 0.2243(t - 36.0247)_+ - 0.3003(t - 37.0247)_+ + 0.0592\sin(2\pi t) + 0.0695\delta_{(t-36.0247)}\sin(2\pi t)$$

where 01/02/1997 was a join point and 01/02/1996 was both join point and knot point. The rate of decrease was 10.73cm/year before 01/02/1996. The linear trend increased at the rate of 11.70cm/year (=22.43-10.73) in year 1996 and then decreased at the rate of 28.33cm/year (=-30.03-11.70). The simple linear regression is

$$x_t = 2.5963 - 0.0694t$$

giving an estimated rate of decrease of 6.94cm/year. A part of S+ output is given below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/02/1996
2: 01/02/1997
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/02/1996
2:
jy= 36.0246575342466 37.027397260274
ky= 36.0246575342466

Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept)  3.8829  0.5591     6.9454  0.0000
        slope.1 -0.1073  0.0163    -6.6015  0.0000
        slope.2  0.2243  0.0594     3.7733  0.0006
        slope.3 -0.3003  0.0720    -4.1698  0.0002
amplitude.sin.1  0.0592  0.0218     2.7156  0.0103
amplitude.sin.2  0.0695  0.0326     2.1303  0.0405

Overall Corrected AIC=-4.08573654412995


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  2.5963  0.3360     7.7272  0.0000
sample.year -0.0694  0.0094    -7.3981  0.0000
Corrected AIC for simple linear regression=-3.40058558733707
```


Depth (m)
0.4
0.2
0.0
-0.2
21/04/1993
21/04/1994
21/04/1995
21/04/1996
21/04/1997
21/04/1998
Date
Join point
Knot point
Threshold regression
Linear trend from threshold regression
Simple regression

(5) CK06I

There are 39 observations. It seems that the input for 21/04/1994 has a mistake. After checking with Mr. Don Bennett, we change the reading from -2.98 to -1.98. The final model is given by

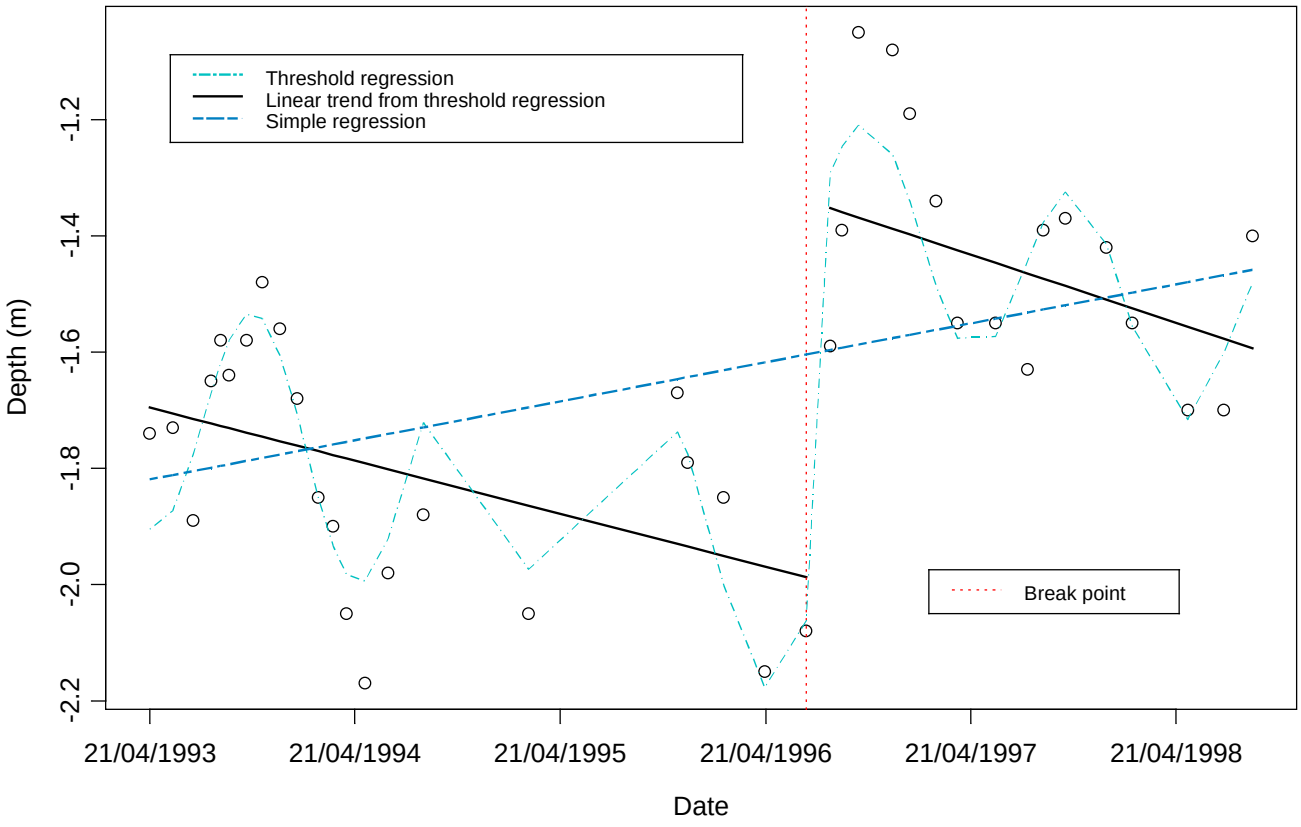
$$x_t = \begin{cases} 1.3353 - 0.0912t - 0.2094\sin(2\pi t) & \text{if} \quad t \le 36.4411 \\ 2.9288 - 0.1171t - 0.1685\sin(2\pi t) & \text{if} \quad t > 36.4411 \end{cases}$$

where the break point was at 02/07/1996. The rates of decrease for these two segments were 9.12cm/year and 11.71cm/year respectively. The size of jump was 63.51 cm. The simple linear regression is

$$x_t = -4.0494 + 0.0671t$$

giving an estimated rate of increase of 6.71cm/year. A part of S+ output is below.

```
input break dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A break date is a date at which all the trend changes)
1: 02/07/1996
2:
by= 36.441095890411

Coefficients:
                 Value Std. Error t value Pr(>|t|)
    (Intercept)  1.3353  0.7078     1.8867  0.0746
        slope.1 -0.0912  0.0206    -4.4359  0.0003
amplitude.sin.1 -0.2094  0.0291    -7.2063  0.0000
Corrected AIC for this segment=  -3.36870245257896

Coefficients:
                 Value Std. Error t value Pr(>|t|)
    (Intercept)  2.9288  2.1406     1.3682  0.1944
        slope.1 -0.1171  0.0571    -2.0519  0.0609
amplitude.sin.1 -0.1685  0.0586    -2.8746  0.0130
Corrected AIC for this segment=  -2.36502792013733

Overall Corrected AIC=-2.9889705008038

-1.98739731606755-(-1.3522825576329)
[1] -0.6351148


Coefficients:
             Value Std. Error t value Pr(>|t|)
(Intercept) -4.0494  0.8483    -4.7734  0.0000
sample.year  0.0671  0.0237     2.8270  0.0076
Corrected AIC for simple linear regression=-1.5948378732466
```


Threshold regression
Linear trend from threshold regression
Simple regression
Break point
Depth (m)
-1.2
-1.4
-1.6
-1.8
-2.0
-2.2
21/04/1993
21/04/1994
21/04/1995
21/04/1996
21/04/1997
21/04/1998
Date

(6) CK07I

There are 40 observations. The optimal model is

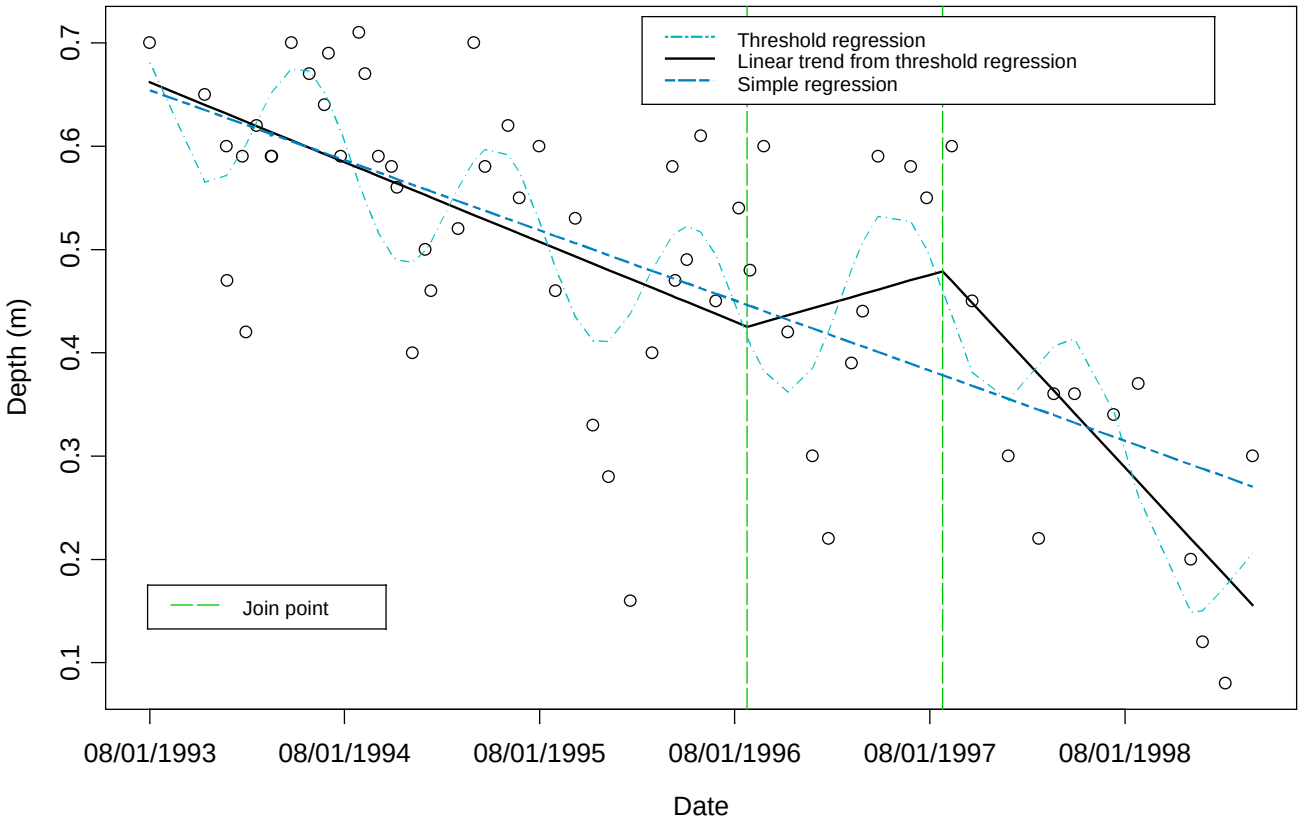
$$x_t = 3.2044 - 0.0771t + 0.1308(t - 36.0247)_+ - 0.2570(t - 37.0247)_+ + 0.0750\sin(2\pi t)$$

where the join points were at 01/02/1996 and 01/02/1997. The estimated linear trend decreased at the rate of 7.71cm/year followed by the increase of 6.37cm/year, and finally decreased at 19.33cm/year. The simple linear regression is

$$x_t = 2.8893 + 0.0678t$$

giving an estimated rate of decrease of 6.78cm/year. The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/02/1996
2: 01/02/1997
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1:
jy= 36.0246575342466 37.027397260274

Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept)  3.2044  0.5516     5.8094  0.0000
        slope.1 -0.0771  0.0159    -4.8374  0.0000
        slope.2  0.1308  0.0618     2.1150  0.0388
        slope.3 -0.2570  0.0881    -2.9179  0.0050
amplitude.sin.1 -0.0750  0.0177    -4.2421  0.0001

Overall Corrected AIC=-3.56326692055979

Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  2.8893  0.3281     8.8070  0.0000
sample.year -0.0678  0.0092    -7.3328  0.0000
Corrected AIC for simple linear regression=-3.25813577016276
```

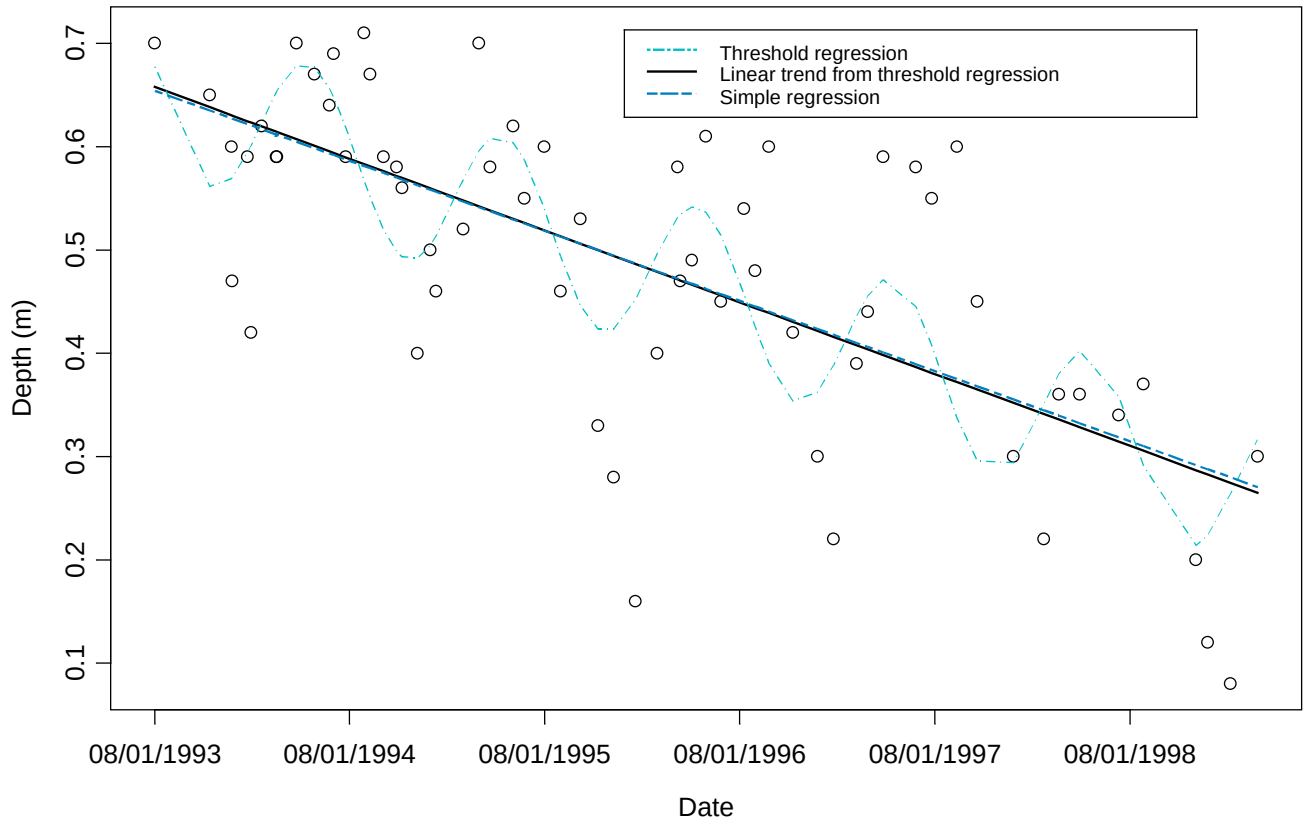

Threshold regression
Linear trend from threshold regression
Simple regression
Join point
Depth (m)
0.1
0.2
0.3
0.4
0.5
0.6
0.7
08/01/1993
08/01/1994
08/01/1995
08/01/1996
08/01/1997
08/01/1998
Date

We also fit a regression with linear and periodic trend as

$$x_t = 2.9452 - 0.0694\,t + 0.0770\sin(2\pi t)$$

giving an estimated rate of decrease of 7.70cm/year. The S+ output is below.

```
Coefficients:
                  Value Std. Error  t value Pr(>|t|)
    (Intercept)   2.9452   0.2917    10.0962   0.0000
        slope.1  -0.0694   0.0082    -8.4394   0.0000
amplitude.sin.1  -0.0770   0.0186    -4.1292   0.0001
Overall Corrected AIC=-3.49135359493228
```



(7) CK08I

There are 39 observations. The final model is selected as

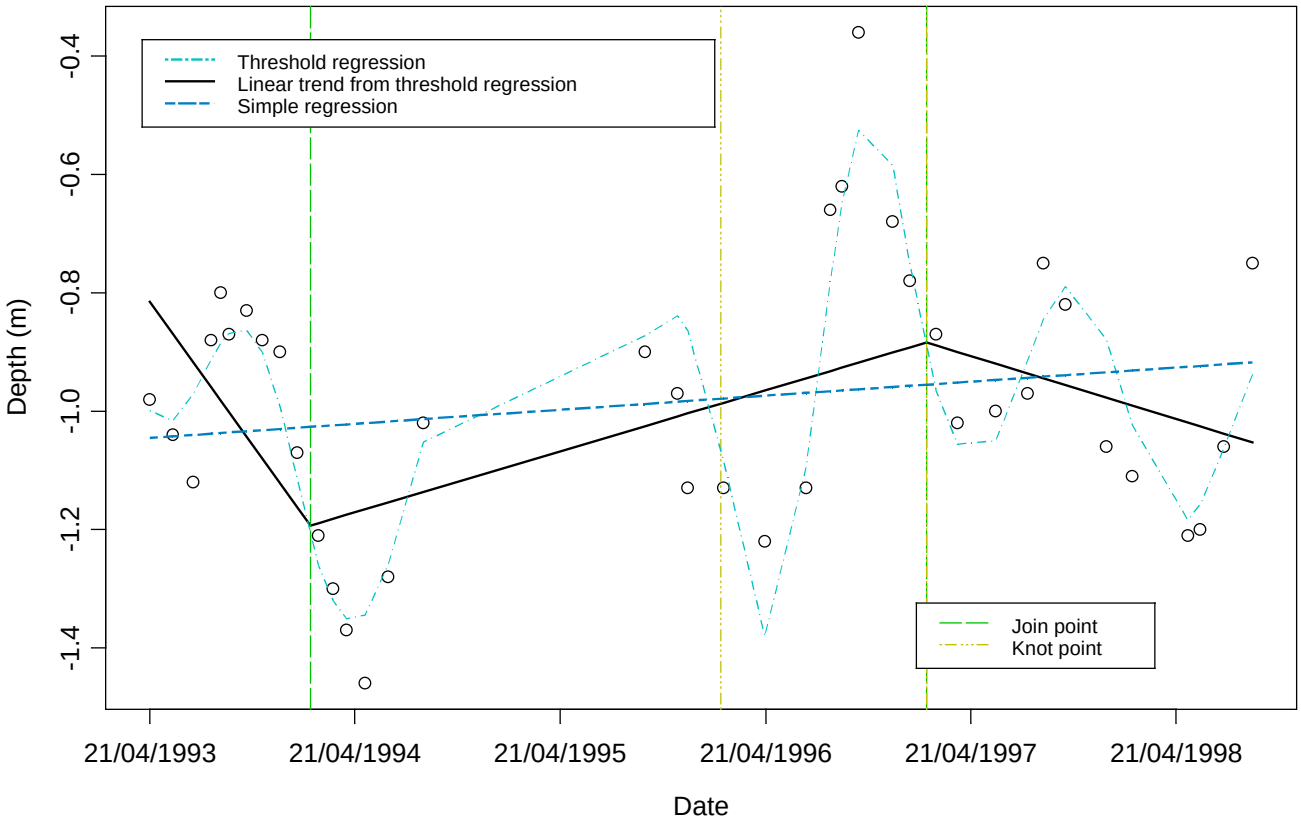
$$x_t = 15.2361 - 0.4829t + 0.5860(t - 34.0247)_+ - 0.2095(t - 37.0247)_+ \\ -0.1847\sin(2\pi t) - 0.2319\delta_{(t-36.0247)}\sin(2\pi t) - 0.2432\delta_{(t-37.0247)}\sin(2\pi t)$$

where the 01/02/1994 was a join point, 01/02/1996 was a knot point and 01/02/1997 acted as both join point and knot point. The estimated linear trend decreased at the rate of 48.29cm/year, then increased at 10.31cm/year and finally decreased at 10.64cm/year. The simple linear regression is

$$x_t = -1.8346 + 0.0207t$$

giving an estimated rate of increase of 2.07cm/year. The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/02/1994
2: 01/02/1997
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/02/1996
2: 01/02/1997
3:
jy= 34.0246575342466 37.027397260274
ky= 36.0246575342466 37.027397260274

Coefficients:
                  Value Std. Error  t value Pr(>|t|)
    (Intercept)  15.2361   3.3777     4.5107   0.0001
        slope.1  -0.4829   0.1001    -4.8258   0.0000
        slope.2   0.5860   0.1122     5.2233   0.0000
        slope.3  -0.2095   0.0569    -3.6792   0.0009
amplitude.sin.1  -0.1847   0.0325    -5.6888   0.0000
amplitude.sin.2  -0.2319   0.0661    -3.5085   0.0014
amplitude.sin.3   0.2432   0.0756     3.2153   0.0030

Overall Corrected AIC=-3.22032011106951

Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -1.8346  0.7275    -2.5218  0.0161
sample.year  0.0237  0.0203     1.1694  0.2497
Corrected AIC for simple linear regression=-1.8565144250895
```


Threshold regression
Linear trend from threshold regression
Simple regression
Join point
Knot point
Depth (m)
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
21/04/1993
21/04/1994
21/04/1995
21/04/1996
21/04/1997
21/04/1998
Date

(8) CK09I.

There are 39 observations. The depths at 19/Jun/1994 and 21/Aug/1994 are extremely small (-0.43 and –0.16). After Don checked the original sheet, we recognised there were input errors. The true values should be 0.57 and 0.84 respectively. Notice also there was no datum between 21/Aug/1994 and 19/09/1995, which makes it difficult to fit the data. Referring the pattern in the other bores in the same area, we make 02/07/1996 as a break point. The final model is given by

$$x_t = \begin{cases} 6.2615 - 0.1591t + 0.3718(t - 35.0247)_+ - 0.2262\sin(2\pi t) & \text{if} \quad t \le 36.4411 \\ 6.7686 - 0.1441t - 0.1828\sin(2\pi t) & \text{if} \quad t > 36.4411 \end{cases}$$

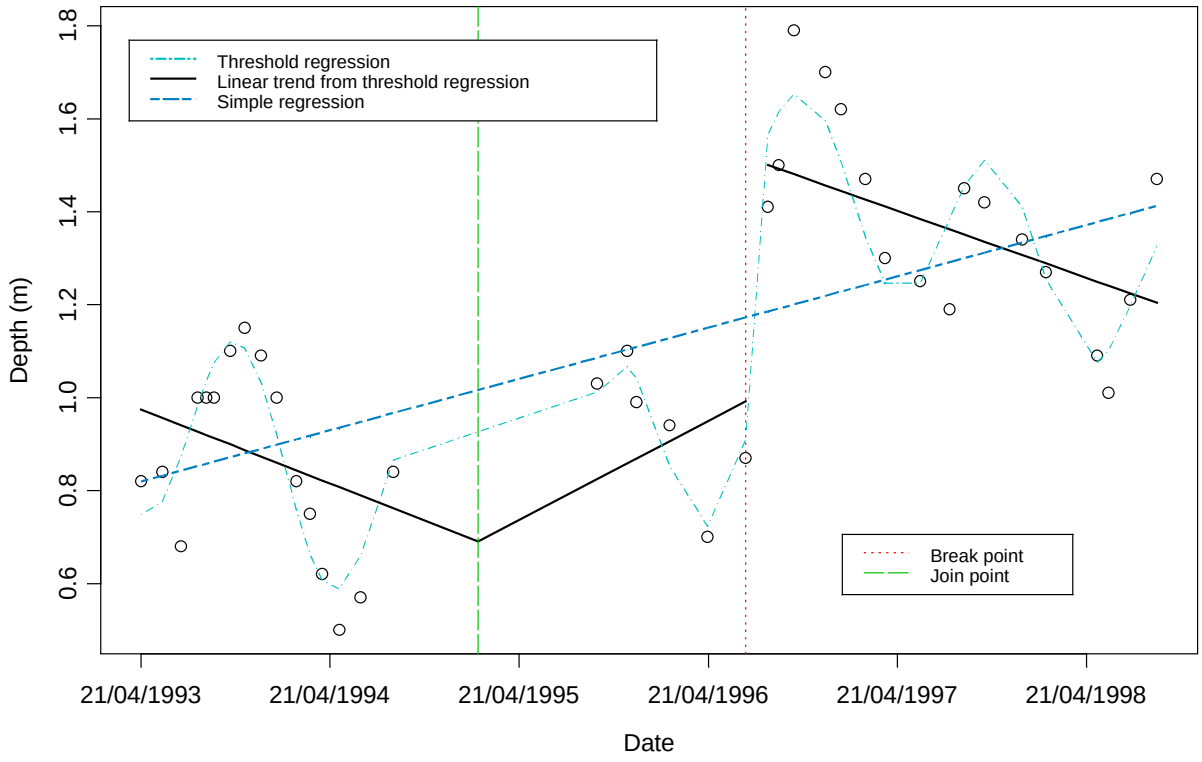
where the break point was at 02/07/1996 and the join point was at 01/02/1995. The estimated linear trend decreased at 15.91cm/year, then increased at 21.27cm/year and finally decreased at 14.41cm/year. The size of jump was 29.93cm. The simple linear regression is

$$x_t = -2.8472 + 0.1103t,$$

giving an estimated rate of increase of 11.03cm/year. A part of S+ output is below.

```
input break dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A break date is a date at which all the trend changes)
1: 02/07/1996
2:
by= 36.441095890411
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/02/1995
2:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1:
jy= 35.0246575342466

Coefficients:
                 Value Std. Error t value Pr(>|t|)
    (Intercept)  6.2615  1.5745     3.9768  0.0009
        slope.1 -0.1591  0.0465    -3.4239  0.0030
        slope.2  0.3718  0.1029     3.6136  0.0020
amplitude.sin.1 -0.2262  0.0232    -9.7502  0.0000
Corrected AIC for this segment=  -1.01208328327946

Coefficients:
                 Value Std. Error t value Pr(>|t|)
    (Intercept)  6.7686  1.6445     4.1159  0.0010
        slope.1 -0.1441  0.0438    -3.2910  0.0054
amplitude.sin.1 -0.1828  0.0447    -4.0895  0.0011
Corrected AIC for this segment=  -2.88237902118769

Overall Corrected AIC=-1.56813120620924

1.20115805549001-(1.50044968573845)
[1] -0.2992916
```

```
Statistical Summary for Linear Regression Model

Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -2.8472  0.8190    -3.4766  0.0013
sample.year  0.1103  0.0229     4.8255  0.0000
Corrected AIC for simple linear regression=-1.61959799484383
```

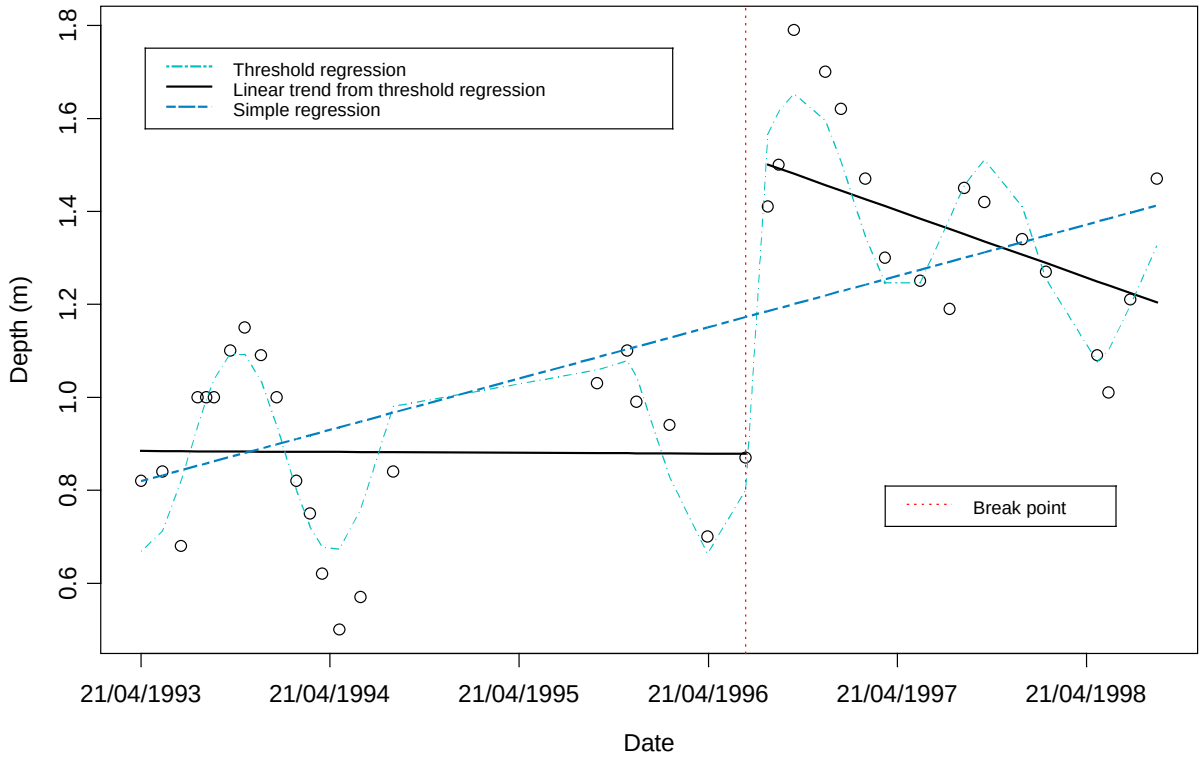


For a comparison, we also fit the following model:

$$x_t = \begin{cases} 0.9445 - 0.0018t - 0.2160\sin(2\pi t) & \text{if} \quad t \le 36.4411 \\ 6.7686 - 0.1441t - 0.1828\sin(2\pi t) & \text{if} \quad t > 36.4411 \end{cases}$$

```
input break dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A break date is a date at which all the trend changes)
1: 02/07/1996
2:
by= 36.441095890411

Coefficients:
                Value Std. Error t value Pr(>|t|)
    (Intercept)  0.9445  0.7165     1.3182  0.2031
```

```
        slope.1 -0.0018  0.0208    -0.0872  0.9314
amplitude.sin.1 -0.2160  0.0294    -7.3358  0.0000

Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept)  6.7686  1.6445     4.1159  0.0010
        slope.1 -0.1441  0.0438    -3.2910  0.0054
amplitude.sin.1 -0.1828  0.0447    -4.0895  0.0011

Overall Corrected AIC=-3.2144885744772
```



(9) CR01I. There are 38 observations. The optimal model is given by

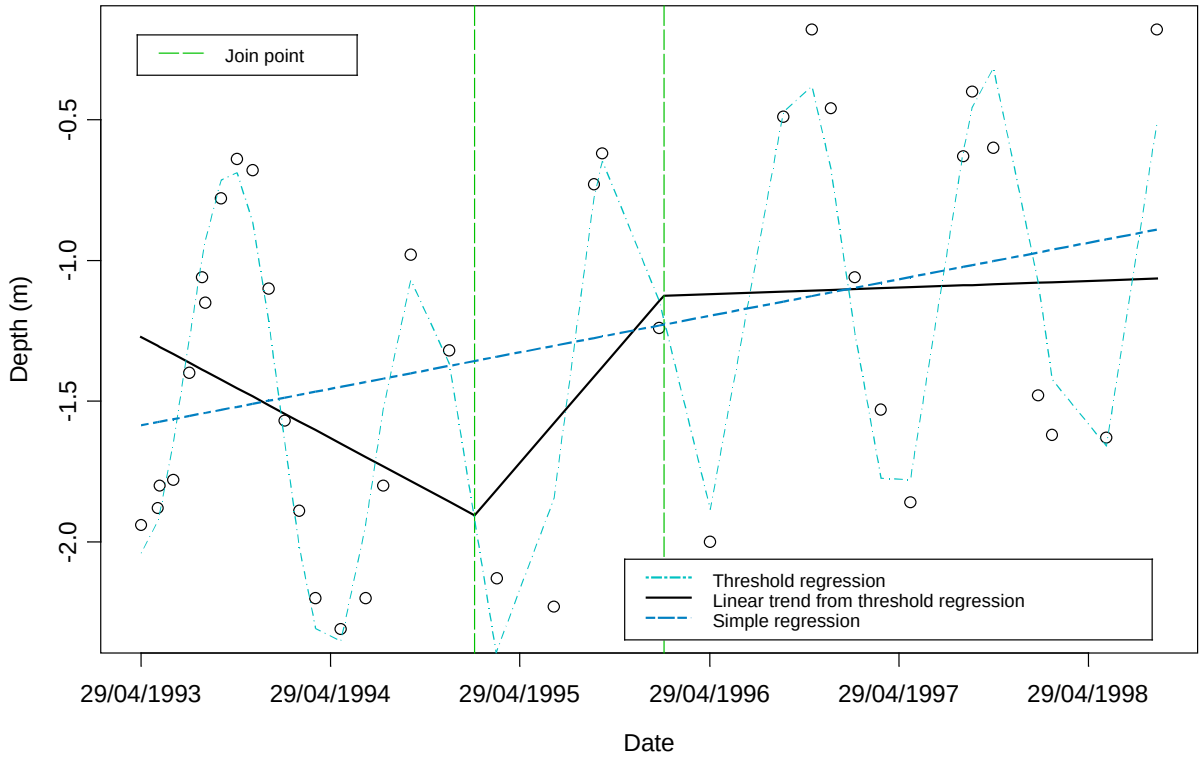
$$x_t = 10.6868 - 0.3595t + 1.1395(t - 35.0247)_+ - 0.7568(t - 36.0247)_+ - 0.7714\sin(2\pi t)$$

where the 01/02/1995 and 01/02/1996 were the join points. The estimated linear trend decreased at the rate of 35.95cm/year, then increased at 78.00cm/year and finally increased at 2.32cm/year. The simple linear regression is

$$x_t = -5.8972 + 0.1296t$$

giving an estimated rate of increase of 12.96cm/year. The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/02/1995
2: 01/02/1996
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1:
jy= 35.0246575342466 36.0246575342466

Coefficients:
                  Value Std. Error  t value Pr(>|t|)
    (Intercept)  10.6868   2.7455     3.8925   0.0005
        slope.1  -0.3595   0.0808    -4.4513   0.0001
        slope.2   1.1395   0.2066     5.5149   0.0000
        slope.3  -0.7568   0.1891    -4.0020   0.0003
amplitude.sin.1  -0.7714   0.0440   -17.5285   0.0000

Overall Corrected AIC=-2.07317195554425


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -5.8972  2.0343    -2.8988  0.0063
sample.year  0.1296  0.0573     2.2605  0.0299
Corrected AIC for simple linear regression=0.139683063054504
```


Join point
Threshold regression
Linear trend from threshold regression
Simple regression
Depth (m)
-0.5
-1.0
-1.5
-2.0
29/04/1993
29/04/1994
29/04/1995
29/04/1996
29/04/1997
29/04/1998
Date

(10) CR02I. There are 39 observations. The depth at 22/Jan/1998 was recorded as 0.9m. As an exception, we choose the beginning of March as the starting point of periodic trend, which improves the results significantly. The starting time is 01/03/1960. I suspect the real reading should be 0.1m. After this correction, the optimal model is given by

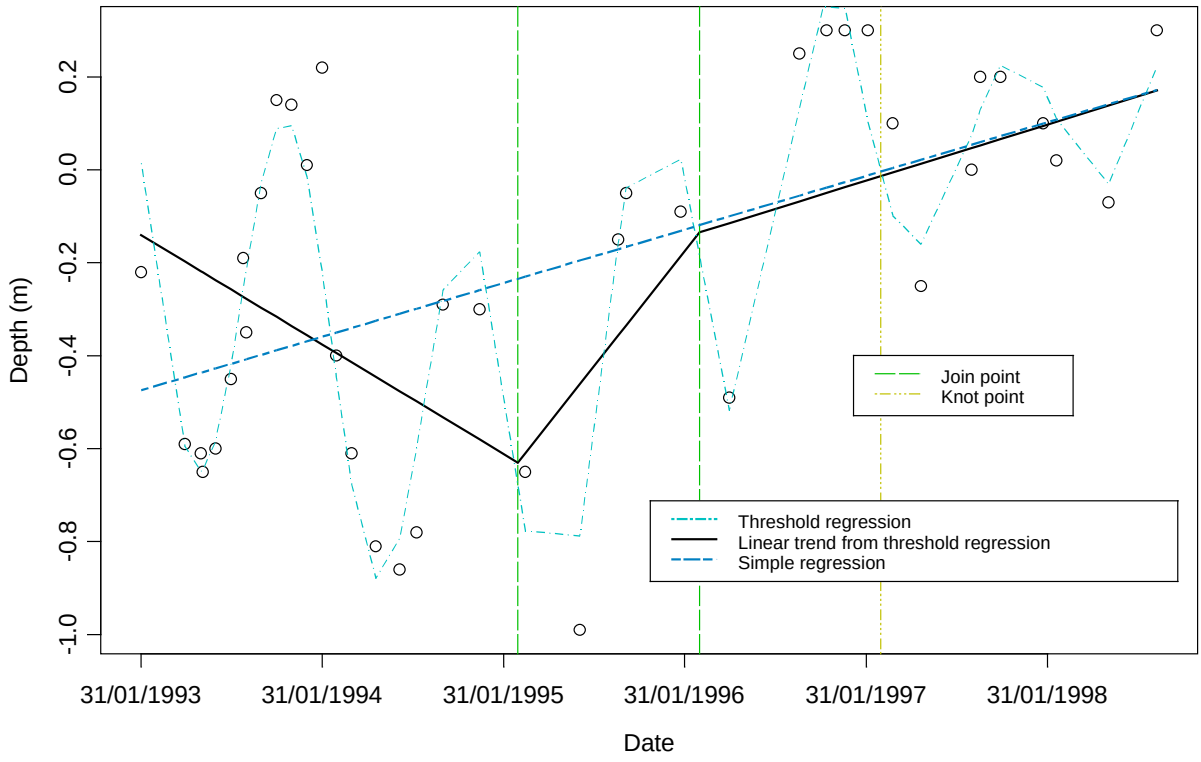
$$x_t = 7.6129 - 0.2354t + 0.7294(t - 35.0292)_+ - 0.3732(t - 36.0247)_+ \\ -0.4350\sin(2\pi t) + 0.2618\delta_{(t-37.0247)}\sin(2\pi t)$$

where the 01/03/1995 and 01/03/1996 were the join points and 01/03/1997 was a knot point. The estimated linear trend decreased at the rate of 23.54cm/year, then increased at 49.40cm/year and 12.08cm/year. The simple linear regression is

$$x_t = -4.2738 + 0.1153t$$

giving an estimated rate of increase of 12.96cm/year. The S+ output is below.

```
input break dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A break date is a date at which all the trend changes)
1:
The program is now in the interactive graphic mode
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/03/1995
2: 01/03/1996
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/03/1997
2:
jy= 35.0219178082192 36.0246575342466
ky= 37.0246575342466

Coefficients:
                  Value Std. Error  t value Pr(>|t|)
    (Intercept)   7.6129   1.6617     4.5814   0.0001
        slope.1  -0.2354   0.0490    -4.8014   0.0000
        slope.2   0.7294   0.1349     5.4062   0.0000
        slope.3  -0.3732   0.1320    -2.8267   0.0079
amplitude.sin.1  -0.4350   0.0354   -12.2701   0.0000
amplitude.sin.2   0.2618   0.0776     3.3748   0.0019

Overall Corrected AIC=-2.79144930936433


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -4.2738  1.0528    -4.0597  0.0002
sample.year  0.1153  0.0298     3.8717  0.0004
Corrected AIC for simple linear regression=-1.12408364622992
```


Depth (m)
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
31/01/1993
31/01/1994
31/01/1995
31/01/1996
31/01/1997
31/01/1998
Date
Join point
Knot point
Threshold regression
Linear trend from threshold regression
Simple regression

(11). CR03I. There are 38 observations. As an exception, we choose the beginning of March as the starting point of periodic trend, which improves the results significantly. The starting time is 01/03/1960. The optimal model is given by

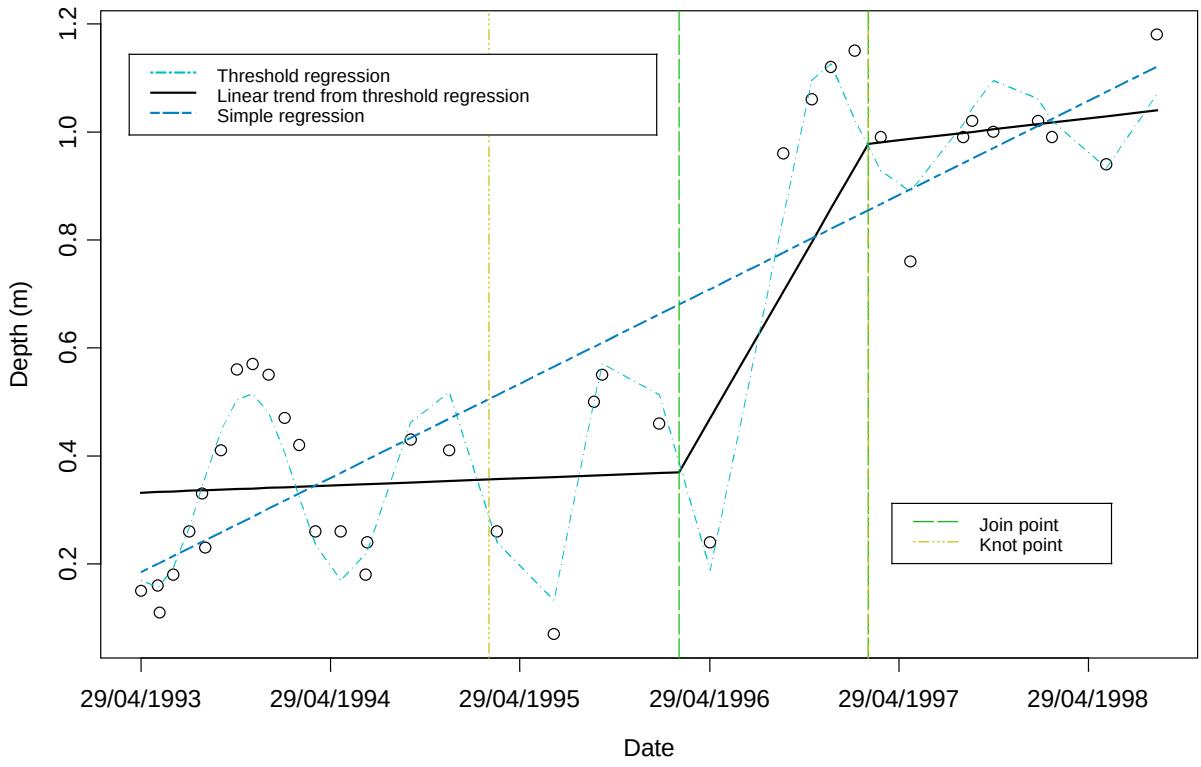
$$x_t = -0.1064 + 0.0132t + 0.5950(t - 36.0247)_+ - 0.5675(t - 37.0247)_+ \\ -0.1773\sin(2\pi t) - 0.1260\delta_{(t-35.0219)}\sin(2\pi t) + 0.2055\delta_{(t-37.0247)}\sin(2\pi t)$$

where the 01/03/1996 was a join point, 01/03/1995 was a knot point , and 01/03/1997 acted as both join point and knot point. The estimated linear trend increased at the rate of 1.32cm/year, 60.83cm/year and 4.07cm/year. The simple linear regression is

$$x_t = -5.6041 + 0.1744t$$

giving an estimated rate of increase of 17.44cm/year. The S+ output is below.

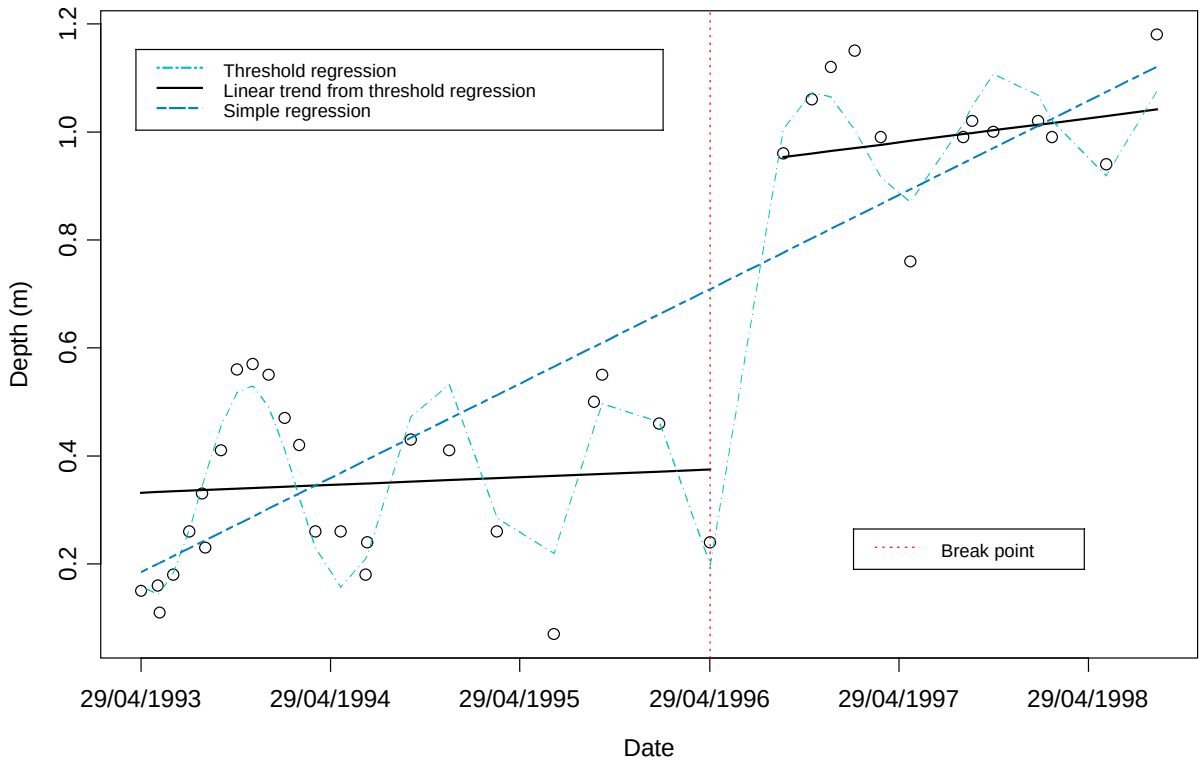
```
The program is now in the interactive graphic mode
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/03/1996
2: 01/03/1997
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/03/1995
2: 01/03/1997
3:
jy= 36.0246575342466 37.0246575342466
ky= 35.0219178082192 37.0246575342466

Coefficients:
                 Value Std. Error t value Pr(>|t|)
    (Intercept) -0.1064  0.5817    -0.1828  0.8561
        slope.1  0.0132  0.0170     0.7786  0.4421
        slope.2  0.5950  0.0647     9.1989  0.0000
        slope.3 -0.5675  0.0882    -6.4341  0.0000
amplitude.sin.1 -0.1773  0.0229    -7.7281  0.0000
amplitude.sin.2 -0.1260  0.0428    -2.9427  0.0061
amplitude.sin.3  0.2055  0.0540     3.8079  0.0006

Overall Corrected AIC=-3.93236342780605


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -5.6041  0.6439    -8.7040  0.0000
sample.year  0.1744  0.0182     9.5914  0.0000

Corrected AIC for simple linear regression=-2.15516570772451
```


Threshold regression
Linear trend from threshold regression
Simple regression
Join point
Knot point
Depth (m)
0.2
0.4
0.6
0.8
1.0
1.2
29/04/1993
29/04/1994
29/04/1995
29/04/1996
29/04/1997
29/04/1998
Date

For comparison, we also fit the following model:

$$x_t = \begin{cases} -0.1384 - 0.0142\,t - 0.1910\sin(2\pi t) & \text{if} \quad t \le 36.2685 \\ -0.6809 - 0.0447\,t - 0.1135\sin(2\pi t) & \text{if} \quad t > 36.2685 \end{cases}$$

```
input break dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A break date is a date at which all the trend changes)
1: 30/04/1996
2:
by= 36.2684931506849

Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept) -0.1384  0.5352    -0.2587  0.7983
        slope.1  0.0142  0.0156     0.9088  0.3733
amplitude.sin.1 -0.1910  0.0195    -9.8058  0.0000

Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept) -0.6809  1.5505    -0.4391  0.6699
        slope.1  0.0447  0.0413     1.0809  0.3051
amplitude.sin.1 -0.1135  0.0387    -2.9308  0.0150

Overall Corrected AIC=-3.91919998354235
```


Threshold regression
Linear trend from threshold regression
Simple regression
Break point
Depth (m)
0.2
0.4
0.6
0.8
1.0
1.2
29/04/1993
29/04/1994
29/04/1995
29/04/1996
29/04/1997
29/04/1998
Date

(12). CR04I. There are 40 observations. There is an input missing at 22/01/1998. As an exception, we choose the beginning of March as the starting point of periodic trend, which improves the results significantly. The starting time is 01/03/1960. The optimal model is given by

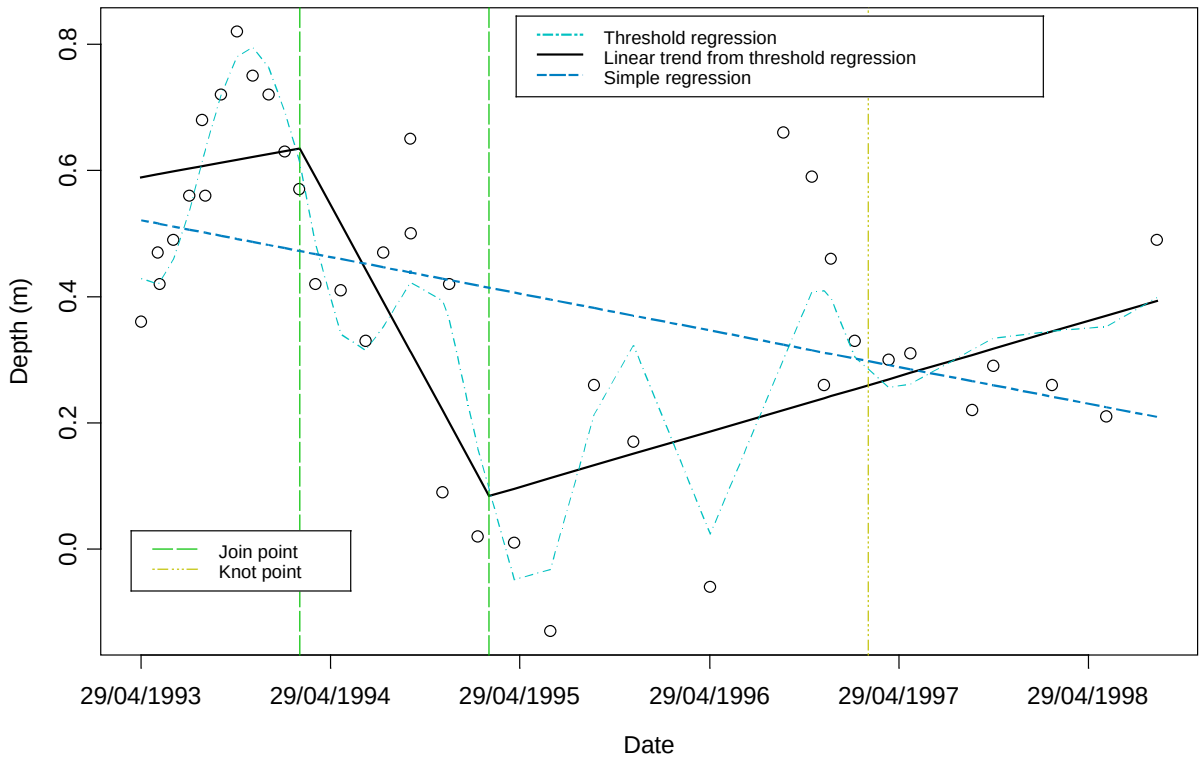
$$x_t = -1.2222 + 0.0546\,t - 0.6051(t - 34.0293)_+ - 0.6382(t - 35.0292)_+ \\ -0.1757\sin(2\pi t) + 0.1577\,\delta_{(t-37.0247)}\sin(2\pi t)$$

where 01/03/1994 and 01/03/1995 were join points and 01/03/1997 was a knot point. The estimated linear trend increased at the rate of 5.46cm/year, and then decreased at 55.05cm/year and finally increased at 8.77cm/year. The simple linear regression is

$$x_t = 2.4488 - 0.0581t$$

giving an estimated rate of decrease of 5.81cm/year. The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/03/1994
2: 01/03/1995
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/03/1997
2:
jy= 34.0219178082192 35.0219178082192
ky= 37.0246575342466

Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept) -1.2222  3.8858    -0.3145  0.7551
        slope.1  0.0546  0.1155     0.4727  0.6395
        slope.2 -0.6051  0.1779    -3.4024  0.0018
        slope.3  0.6382  0.0990     6.4485  0.0000
amplitude.sin.1 -0.1757  0.0320    -5.4861  0.0000
amplitude.sin.2  0.1577  0.0742     2.1263  0.0410

Overall Corrected AIC=-2.8817153277021


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  2.4488  0.7453     3.2855  0.0022
sample.year -0.0581  0.0211    -2.7486  0.0092
Corrected AIC for simple linear regression=-1.94446924936753
```


Threshold regression
Linear trend from threshold regression
Simple regression
Join point
Knot point
Depth (m)
0.0
0.2
0.4
0.6
0.8
29/04/1993
29/04/1994
29/04/1995
29/04/1996
29/04/1997
29/04/1998
Date

(13) CR05I. There are 40 observations. The model fit without break points is given by

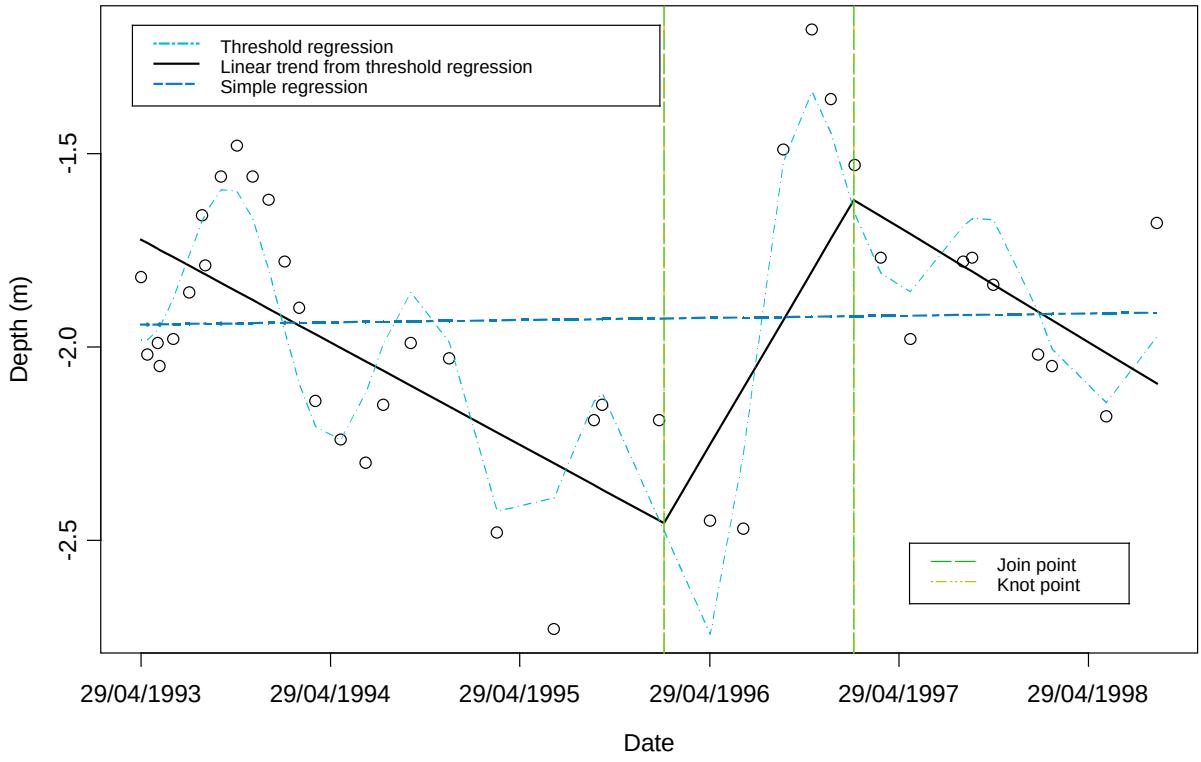
$$x_t = 7.0995 - 0.2652t + 1.0979(t - 36.0247)_+ - 1.1294(t - 37.0274)_+ \\ -0.2616\sin(2\pi t) - 0.2332\delta_{(t-36.0247)}\sin(2\pi t) + 0.3270\delta_{(t-37.0274)}\sin(2\pi t)$$

where 01/02/1996 and 01/02/1997 acted as both join points and knot points. The estimated linear trend decreased at the rate of 26.52cm/year, and then increased at 83.27cm/year and finally decreased at 29.67cm/year. The simple linear regression is

$$x_t = -2.1298 + 0.0056t$$

giving an estimated rate of increase of 0.56cm/year (no trend). The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/02/1996
2: 01/02/1997
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/02/1996
2: 01/02/1997
3:
jy= 36.0246575342466 37.027397260274
ky= 36.0246575342466 37.027397260274

Coefficients:
                 Value Std. Error t value Pr(>|t|)
    (Intercept)  7.0995  1.2788     5.5517  0.0000
        slope.1 -0.2652  0.0373    -7.1132  0.0000
        slope.2  1.0979  0.1459     7.5229  0.0000
        slope.3 -1.1294  0.1926    -5.8637  0.0000
amplitude.sin.1 -0.2616  0.0462    -5.6592  0.0000
amplitude.sin.2 -0.2332  0.1109    -2.1030  0.0432
amplitude.sin.3  0.3270  0.1271     2.5734  0.0148

Overall Corrected AIC=-2.3751930652303


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -2.1298  1.0962    -1.9429  0.0595
sample.year  0.0056  0.0309     0.1822  0.8564
Corrected AIC for simple linear regression=-1.05464570130578
```

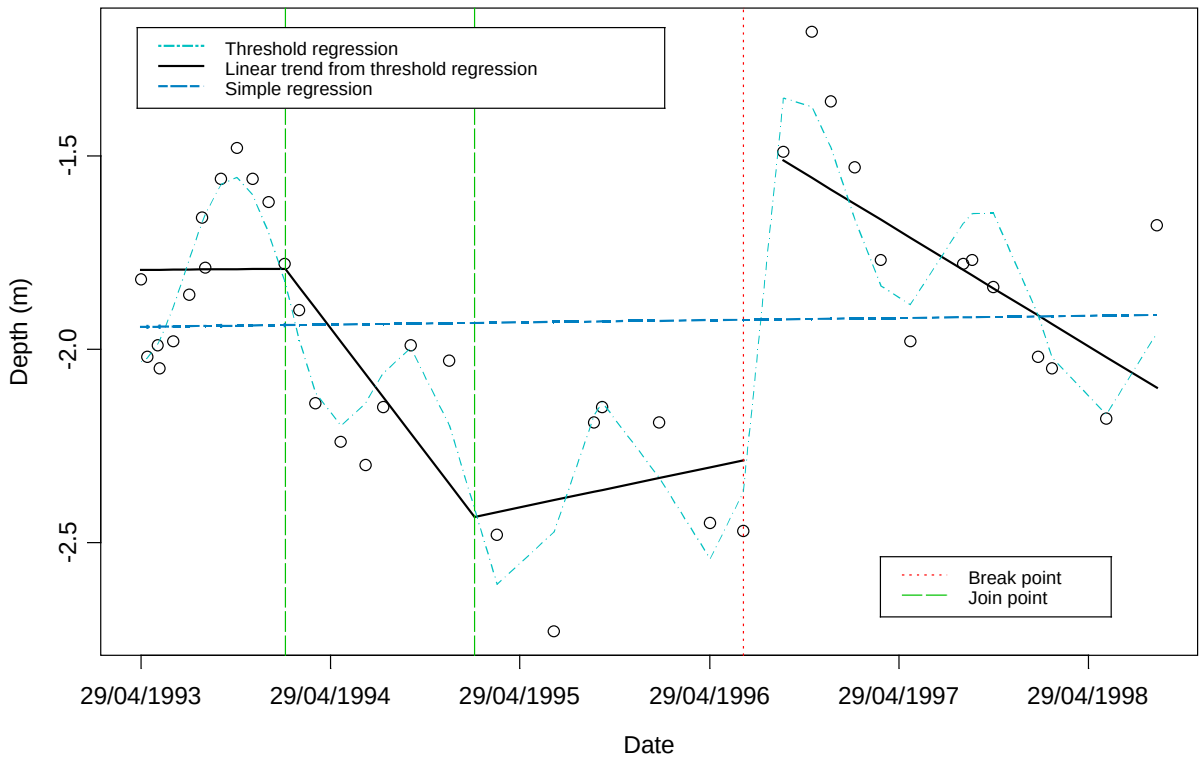


As a comparison, we also fit a model with a break point at 03/07/1996.

$$x_t = \begin{cases} -1.8988 + 0.0031t - 0.6445(t-34.0247)_+ + 0.7448(t-35.0247)_+ - 0.2386\sin(2\pi t) & \text{if} \quad t \le 36.4438 \\ 9.4007 - 0.2977\,t - 0.1950\sin(2\pi t) & \text{if} \quad t > 36.4438 \end{cases}$$

```
input break dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A break date is a date at which all the trend changes)
1: 03/07/1996
2:
by= 36.4438356164384

input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/02/1994
2: 01/02/1995
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1:
jy= 34.0246575342466 35.0246575342466

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

```
    (Intercept) -1.8988  3.7850    -0.5017  0.6209
        slope.1  0.0031  0.1124     0.0278  0.9781
        slope.2 -0.6445  0.1830    -3.5221  0.0019
        slope.3  0.7448  0.1609     4.6285  0.0001
amplitude.sin.1 -0.2386  0.0330    -7.2213  0.0000


Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept)  9.4007  2.8410     3.3090  0.0079
        slope.1 -0.2977  0.0756    -3.9368  0.0028
amplitude.sin.1 -0.1950  0.0640    -3.0475  0.0123

Overall Corrected AIC=-2.68644156929122
```



((14) CR06I.There are 38 observations. The final model is given by

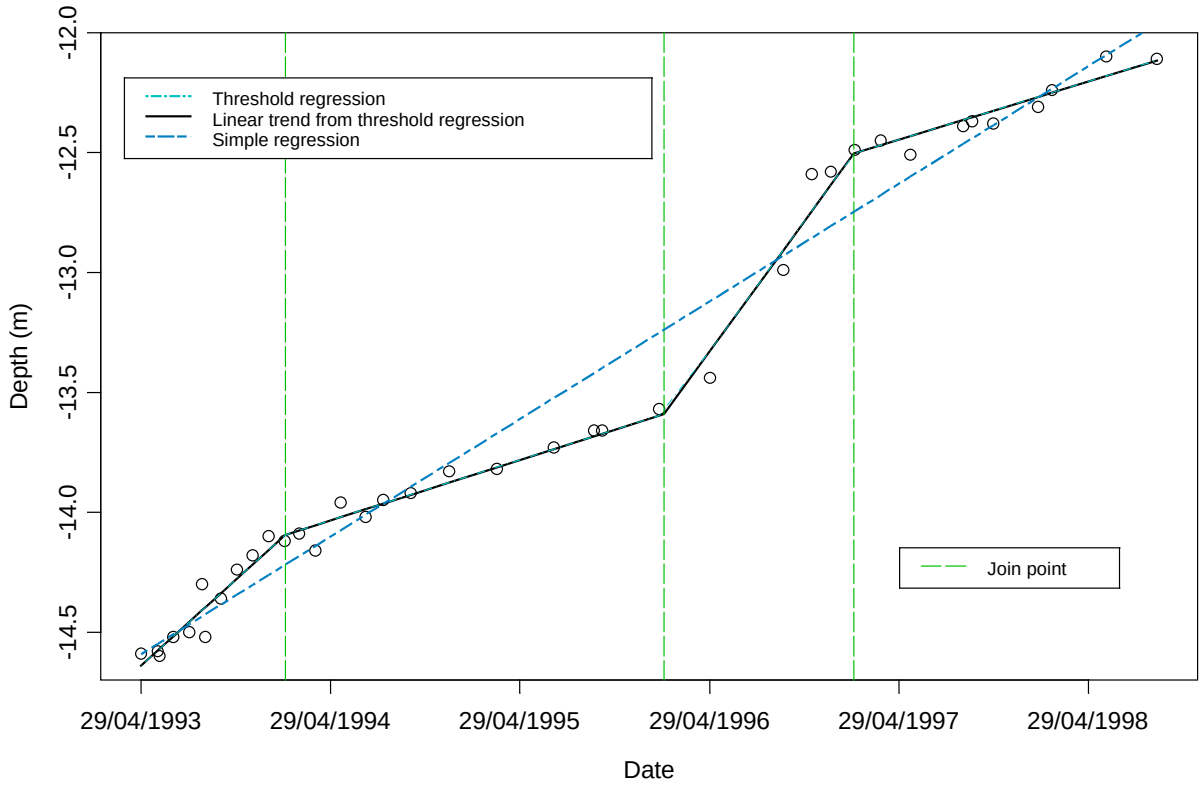
$$x_t = -38.4544 + 0.7160\,t - 0.4641(t - 34.0247)_+ + 0.8315(t - 36.0247)_+ - 0.8407(t - 37.0247)_+$$

where the join points were at 01/02/1994, 01/02/1996 and 01/02/1997. The estimated linear trend increased at 71.60cm/year, 25.19cm/year, 108.34cm/year and 24.27cm/year. The simple linear regression is

$$x_t = -30.8915 + 0.4900\,t$$

giving an estimated rate of increase of 49.00cm/year (no trend). The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/02/1994
2: 01/02/1996
3: 01/02/1997
4:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1:
jy= 34.0246575342466 36.0246575342466 37.027397260274
Please provide  1  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 0
2:

Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept) -38.4544   1.9262   -19.9641   0.0000
    slope.1   0.7160   0.0571    12.5332   0.0000
    slope.2  -0.4641   0.0720    -6.4439   0.0000
    slope.3   0.8315   0.0627    13.2645   0.0000
    slope.4  -0.8407   0.0708   -11.8786   0.0000

Overall Corrected AIC=-4.33033342321


Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept) -30.8915   0.5021   -61.5207   0.0000
sample.year   0.4900   0.0142    34.6267   0.0000

Corrected AIC for simple linear regression=-2.6584322271009
```


Threshold regression
Linear trend from threshold regression
Simple regression
Join point
Depth (m)
-12.0
-12.5
-13.0
-13.5
-14.0
-14.5
29/04/1993
29/04/1994
29/04/1995
29/04/1996
29/04/1997
29/04/1998
Date

(15) CR07I. There are 62 observations. As an exception, we choose the middle of March as the starting point of periodic trend, which improves the results significantly. The starting time is 15/03/1960. The final model is given by

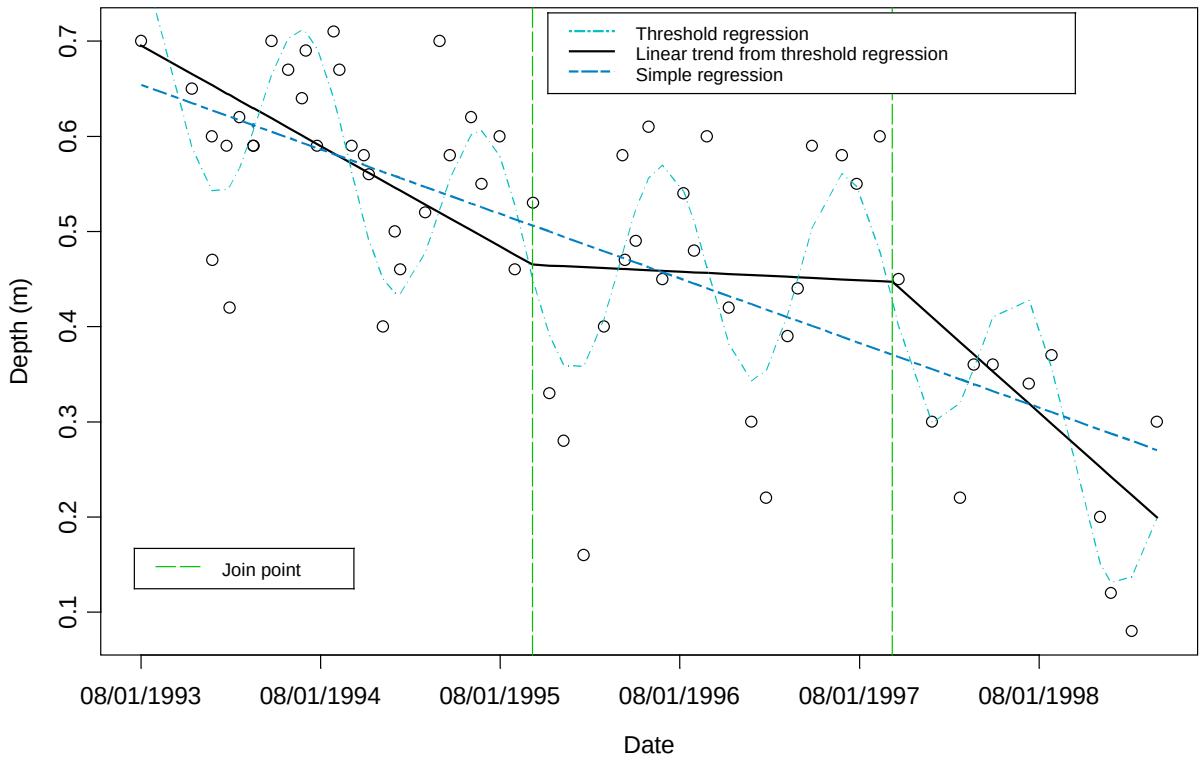
$$x_t = 4.1661 - 0.1057t + 0.0967(t - 35.0219)_+ - 0.1591(t - 37.0247)_+ - 0.1112\sin(2\pi t)$$

where the join points were 15/03/1995 and 15/03/1997. The estimated linear trend decreased at 10.57cm/year, 0.90cm/year and 16.81cm/year. The simple linear regression is

$$x_t = 2.8813 - 0.0678t$$

giving an estimated rate of decrease of 6.78cm/year (no trend). The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 15/03/1995
2: 15/03/1997
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1:
jy= 35.0219178082192 37.0246575342466

Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept)  4.1661  0.6477     6.4316  0.0000
        slope.1 -0.1057  0.0190    -5.5683  0.0000
        slope.2  0.0967  0.0343     2.8192  0.0066
        slope.3 -0.1591  0.0495    -3.2117  0.0022
amplitude.sin.1 -0.1112  0.0136    -8.1548  0.0000

Overall Corrected AIC=-4.05700124708287


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  2.8813  0.3270     8.8119  0.0000
sample.year -0.0678  0.0092    -7.3328  0.0000

Corrected AIC for simple linear regression=-3.25813577016276
```


Threshold regression
Linear trend from threshold regression
Simple regression
Join point
Depth (m)
0.1
0.2
0.3
0.4
0.5
0.6
0.7
08/01/1993
08/01/1994
08/01/1995
08/01/1996
08/01/1997
08/01/1998
Date

(16) CRTOWN.

(17) DC01M. There are 70 observations, most of which have value of –4.95. I suspect that the bore was dried up frequently. So no analysis has been done.

(18) DC02M. There are 74 observations. As an exception, we choose the last month of each year as the starting point of periodic trend, which improves the results significantly. The starting time is 01/12/1960. The final model is

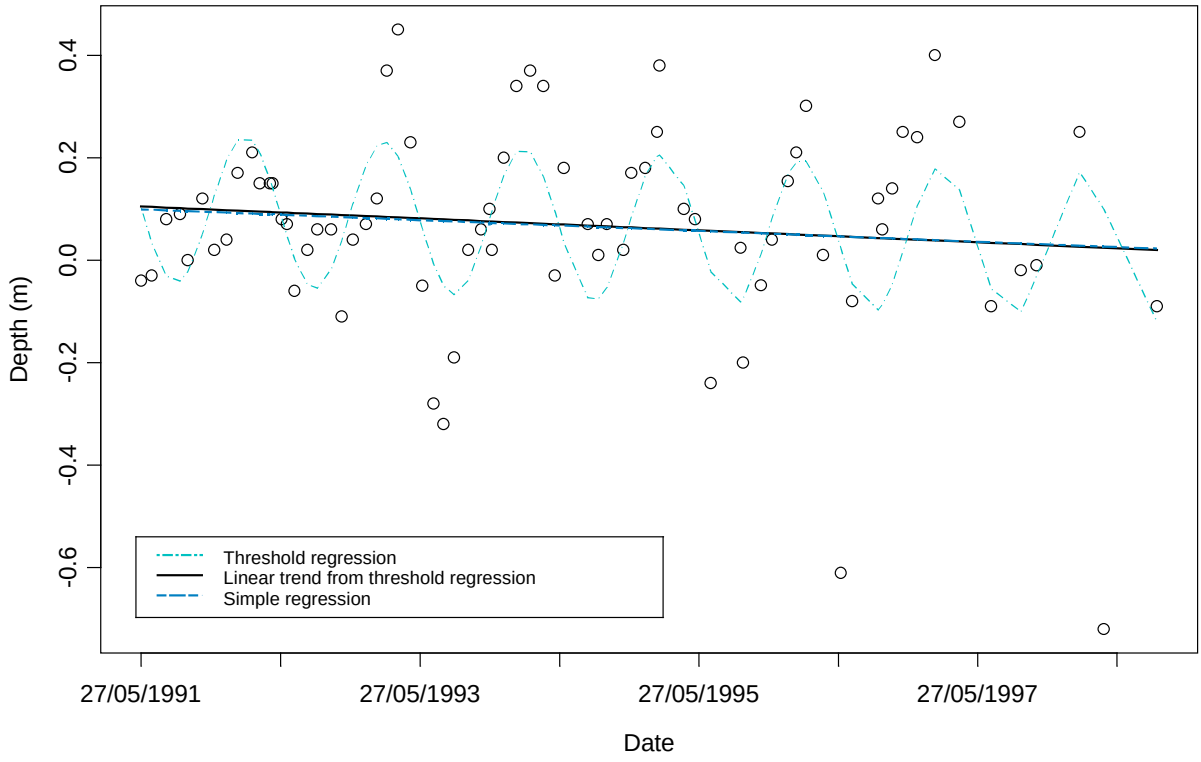
$$x_t = 0.4598 - 0.0116t + 0.1459\sin(2\pi t)$$

giving an estimated rate of decrease of 1.16cm/year (no trend). The simple linear regression is

$$x_t = 0.4200 - 0.0105t$$

giving an estimated rate of decrease of 1.05cm/year (no trend). The S+ output is below.

```
Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept)  0.4598  0.3467     1.3262  0.1890
        slope.1 -0.0116  0.0103    -1.1279  0.2632
amplitude.sin.1  0.1459  0.0286     5.0936  0.0000

Overall Corrected AIC=-2.45013986676965


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  0.4200  0.4022     1.0444  0.2998
sample.year -0.0105  0.0120    -0.8792  0.3822
Corrected AIC for simple linear regression=-2.15529584118873
```


Depth (m)
0.4
0.2
0.0
-0.2
-0.4
-0.6
Threshold regression
Linear trend from threshold regression
Simple regression
27/05/1991
27/05/1993
27/05/1995
27/05/1997
Date

(19) DC03M. There are 80 observations. As an exception, we choose the last month of each year as the starting point of periodic trend, which improves the results significantly. The starting time is 01/12/1960. The final model is

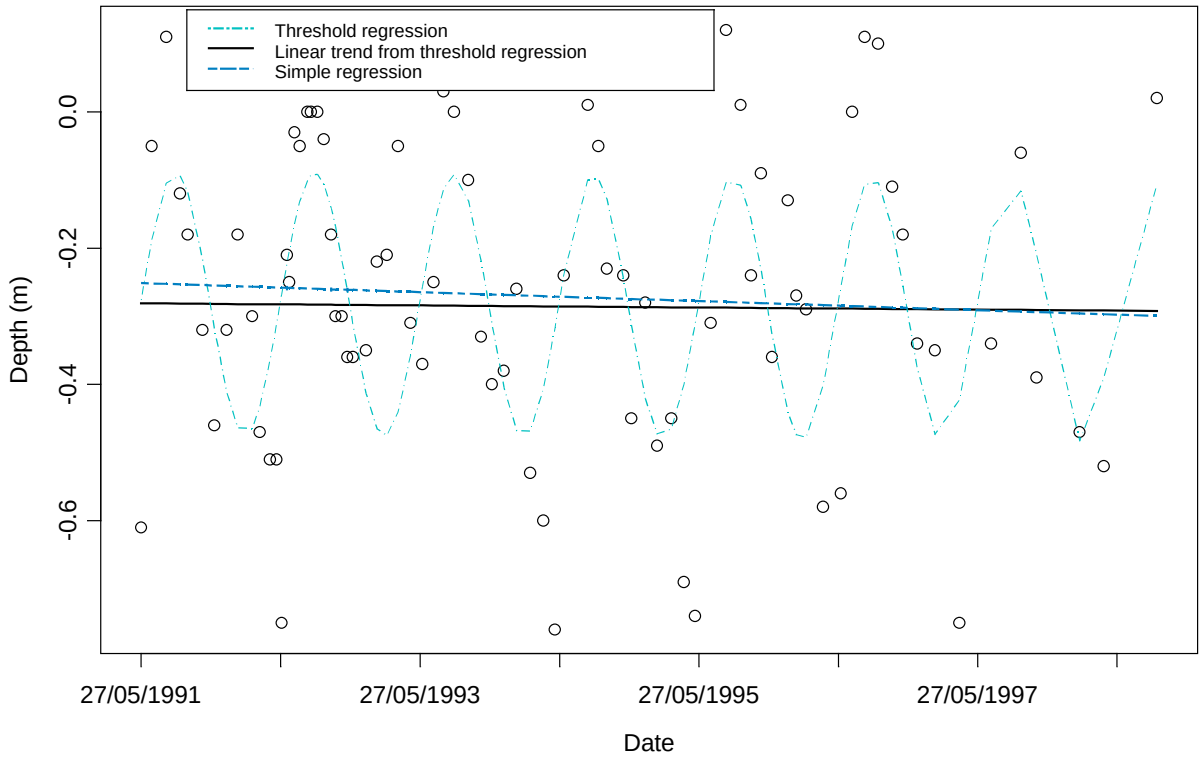
$$x_t = -0.2352 - 0.0015t - 0.1924\sin(2\pi t)$$

giving an estimated rate of decrease of 0.15cm/year (no trend). The simple linear regression is

$$x_t = -0.0498 - 0.0066t$$

giving an estimated rate of decrease of 0.66cm/year (no trend). The S+ output is below.

```
Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept) -0.2352  0.3480    -0.6758  0.5012
        slope.1 -0.0015  0.0104    -0.1449  0.8852
amplitude.sin.1 -0.1924  0.0286    -6.7247  0.0000
Overall Corrected AIC=-2.38219971815686

Coefficients:
               Value Std. Error t value Pr(>|t|)
(Intercept) -0.0498  0.4342    -0.1147  0.9090
sample.year -0.0066  0.0130    -0.5099  0.6115
Corrected AIC for simple linear regression=-1.93530672161047
```



(20) DC04M. There are 78 observations. As an exception, we choose the beginning of each year as the starting point of periodic trend, which improves the results significantly. The starting time is 01/01/1960. The final model is

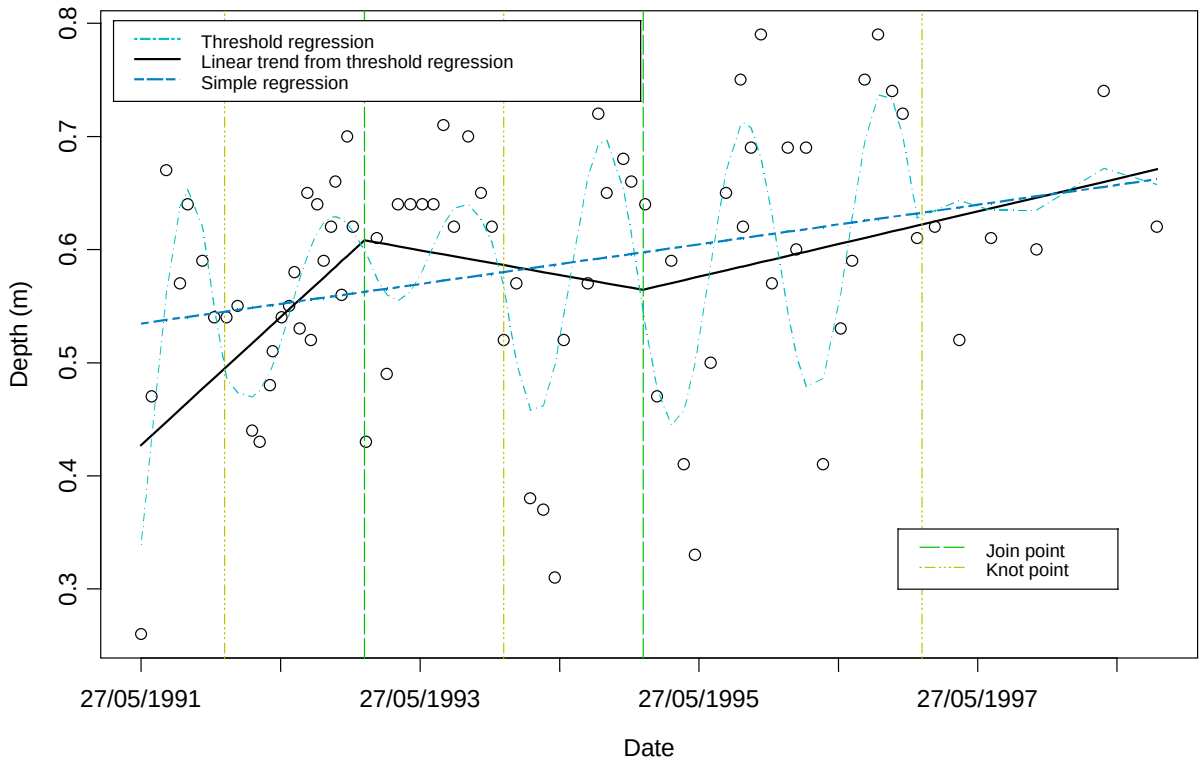
$$x_t = -3.1215 + 0.1129\,t - 0.1348(t-33.0247)_+ + 0.0507(t-35.0274)_+ \\ -0.1881\sin(2\pi t) + 0.1395\,\delta_{(t-32.0247)}\sin(2\pi t) - 0.0785\,\delta_{(t-34.0274)}\sin(2\pi t) + 0.1407\,\delta_{(t-37.0274)}\sin(2\pi t)$$

where the join points were 01/01/1993 and 01/01/1995, and the knot points were 01/01/1992, 01/01/1994 and 01/01/1997. The estimated linear trend increased at 11.29cm/year, then decreased at 2.19cm/year and finally increased at 2.88cm/year. The simple linear regression is

$$x_t = -0.0155 + 0.0175\,t,$$

giving the estimated rate of increase of 1.75cm/year. The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/01/1993
2: 01/01/1995
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/01/1992
2: 01/01/1994
3: 01/01/1997
4:
jy= 33.0246575342466 35.0246575342466
ky= 32.0219178082192 34.0246575342466 37.027397260274

Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept) -3.1215  0.9846    -3.1703  0.0023
        slope.1  0.1129  0.0303     3.7323  0.0004
        slope.2 -0.1348  0.0413    -3.2667  0.0017
        slope.3  0.0507  0.0255     1.9882  0.0507
amplitude.sin.1 -0.1881  0.0502    -3.7437  0.0004
amplitude.sin.2  0.1395  0.0555     2.5136  0.0143
amplitude.sin.3 -0.0785  0.0273    -2.8775  0.0053
amplitude.sin.4  0.1407  0.0436     3.2272  0.0019
Overall Corrected AIC=-3.98278421795115


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -0.0155  0.2218    -0.0699  0.9445
sample.year  0.0175  0.0065     2.7109  0.0083
Corrected AIC for simple linear regression=-3.42550424458452
```

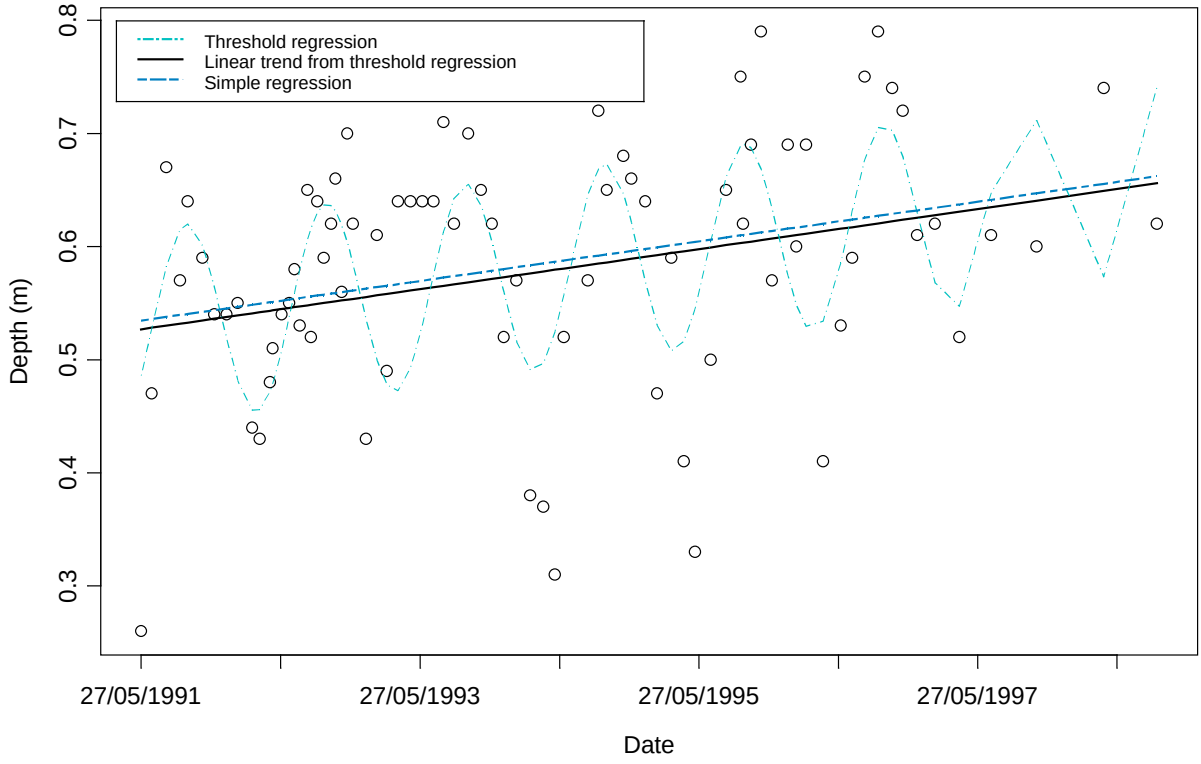


For a comparison, we also fit the following model:

$$x_t = -0.0293 + 0.0177t - 0.0872\sin(2\pi t)$$

giving an estimated rate of increase of 1.77cm/year. The S+ output is below.

```
Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept) -0.0293  0.1793    -0.1632  0.8708
        slope.1  0.0177  0.0052     3.3919  0.0011
amplitude.sin.1 -0.0872  0.0136    -6.4303  0.0000
Overall Corrected AIC=-3.84900624632644
```


Threshold regression
Linear trend from threshold regression
Simple regression
Depth (m)
0.3
0.4
0.5
0.6
0.7
0.8
27/05/1991
27/05/1993
27/05/1995
27/05/1997
Date

(21) DC10I. There are 64 observations. The final model is given by

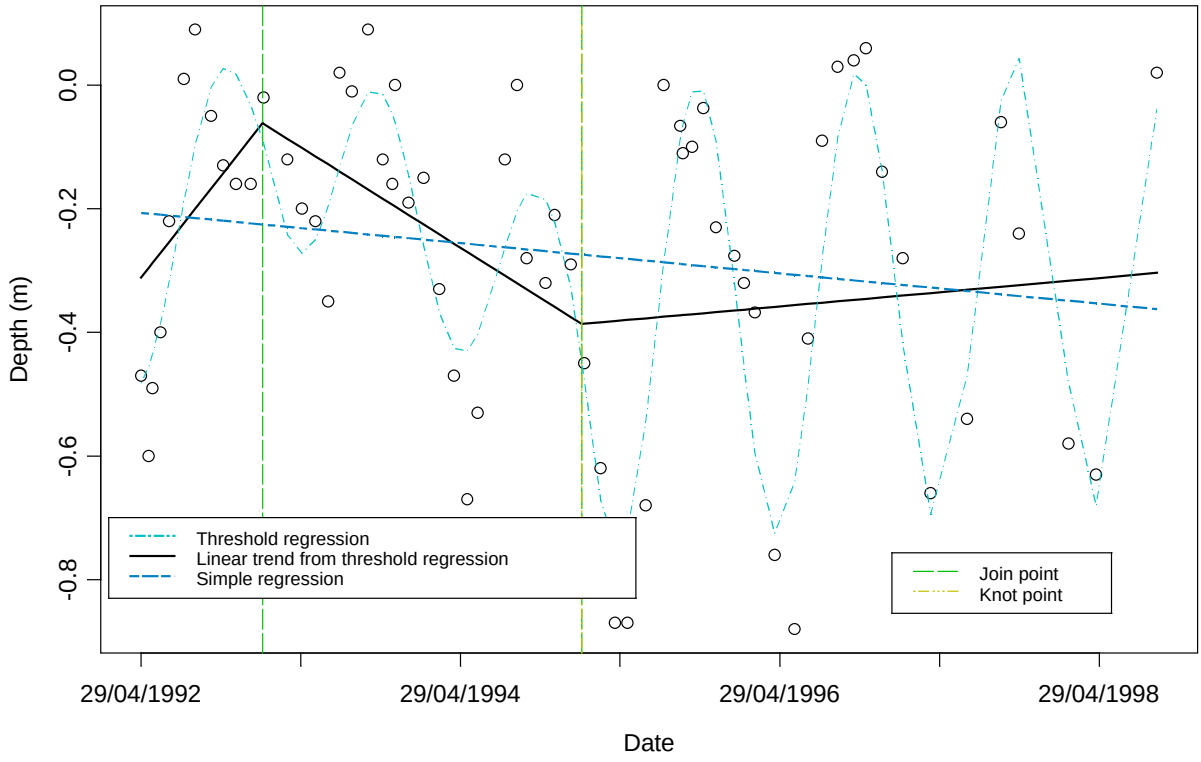
$$x_t = -10.8720 + 0.3274\,t - 0.4899(t - 33.0247)_+ + 0.1855(t - 35.0274)_+ \\ -0.1717\sin(2\pi t) + 0.1970\,\delta_{(t-35.0247)}\sin(2\pi t)$$

where the join point was 01/02/1993, and the 01/02/1995 acted as both a join point a knot point. The estimated linear trend increased at the rate of 32.74cm/year, then decreased at 16.25cm/year and finally increased at 2.30cm/year. The simple linear regression is

$$x_t = 0.5815 - 0.0244\,t,$$

giving the estimated rate of decrease of 2.44cm/year. The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/02/1993
2: 01/02/1995
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/02/1995
2:
jy= 33.0246575342466 35.0246575342466
ky= 35.0246575342466

Coefficients:
                  Value Std. Error  t value Pr(>|t|)
    (Intercept) -10.8720   3.5727    -3.0431   0.0035
        slope.1   0.3274   0.1091     3.0004   0.0040
        slope.2  -0.4899   0.1299    -3.7715   0.0004
        slope.3   0.1855   0.0465     3.9899   0.0002
amplitude.sin.1  -0.1717   0.0315    -5.4547   0.0000
amplitude.sin.2  -0.1970   0.0454    -4.3380   0.0001

Overall Corrected AIC=-2.94246812742192


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  0.5815  0.6617     0.8788  0.3829
sample.year -0.0244  0.0189    -1.2899  0.2019
Corrected AIC for simple linear regression=-1.62635903127243
```


Depth (m)
0.0
-0.2
-0.4
-0.6
-0.8
29/04/1992
29/04/1994
29/04/1996
29/04/1998
Date
Threshold regression
Linear trend from threshold regression
Simple regression
Join point
Knot point

(22) DC12M. There are 67 observations. The final model is given by

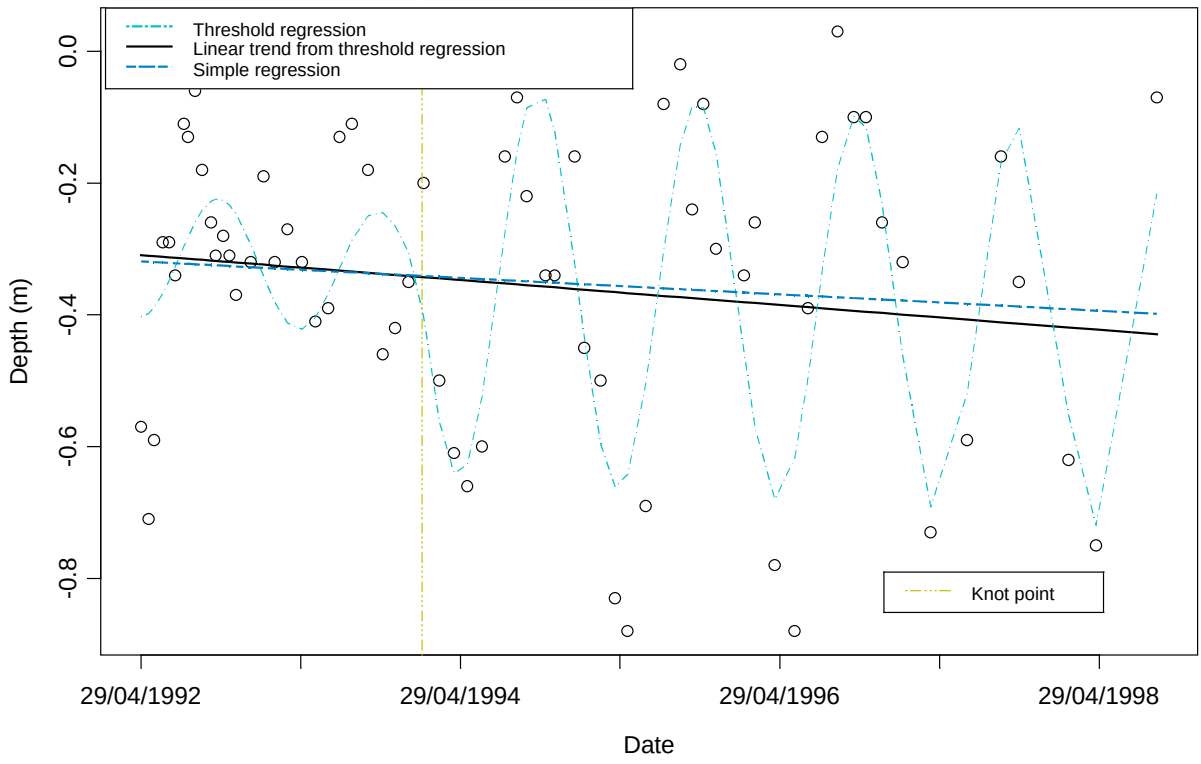
$$x_t = 0.3008 - 0.0189t - 0.0944\sin(2\pi t) - 0.2033\delta_{(t-34.0247)}\sin(2\pi t)$$

where the knot point was at 01/02/1994. The estimated linear trend decreased at the rate of 1.89cm/year. The simple linear regression is

$$x_t = 0.0823 - 0.0124t,$$

giving the estimated rate of decrease of 1.24cm/year. The S+ output is below.

```
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/02/1994
2:
ky= 34.0246575342466

Coefficients:
                 Value Std. Error t value Pr(>|t|)
    (Intercept)  0.3008  0.3583     0.8393  0.4045
        slope.1 -0.0189  0.0103    -1.8329  0.0715
amplitude.sin.1 -0.0944  0.0392    -2.4047  0.0191
amplitude.sin.2 -0.2033  0.0510    -3.9856  0.0002

Overall Corrected AIC=-2.71543757936362


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  0.0823  0.5472     0.1504  0.8809
sample.year -0.0124  0.0158    -0.7897  0.4326
Corrected AIC for simple linear regression=-1.88323517565973
```


Threshold regression
Linear trend from threshold regression
Simple regression
Knot point
Depth (m)
0.0
-0.2
-0.4
-0.6
-0.8
29/04/1992
29/04/1994
29/04/1996
29/04/1998
Date

(23) DC14I. There are 68 observations. The optimal model is given by

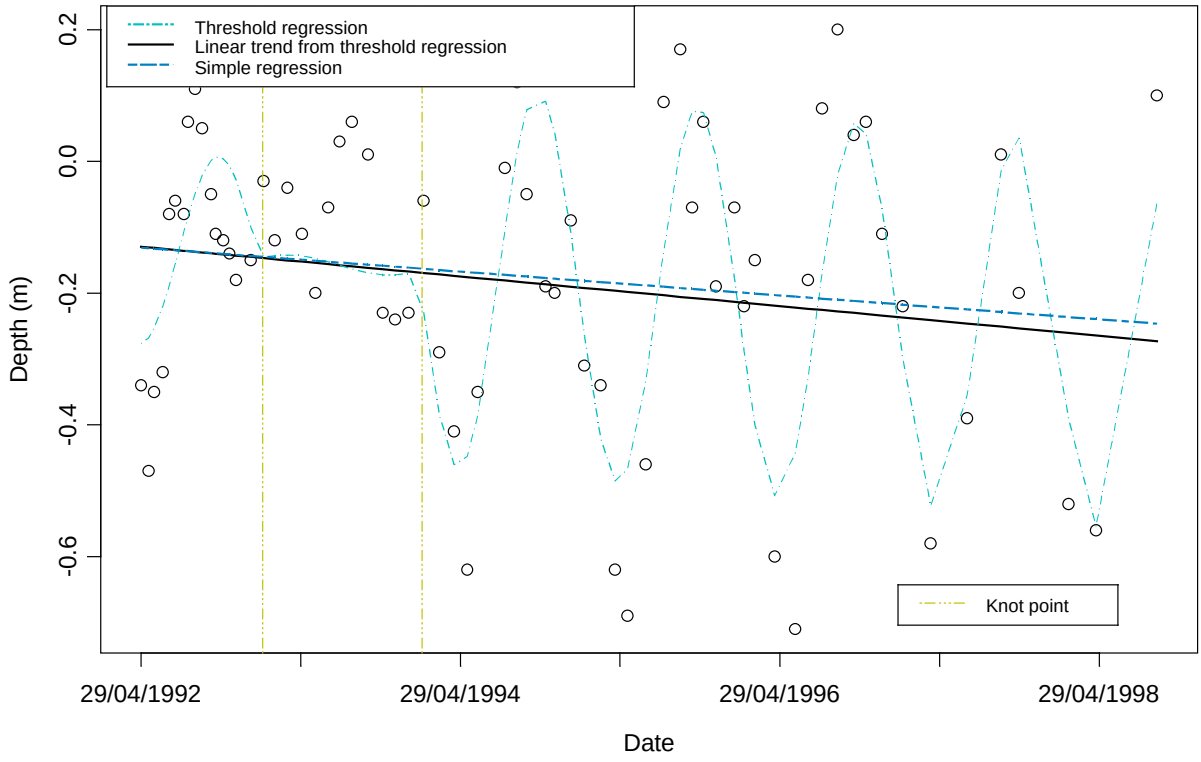
$$x_t = 0.5958 - 0.0225t - 0.1475\sin(2\pi t) + 0.1563\delta_{(t-33.0247)}\sin(2\pi t) - 0.2992\delta_{(t-34.0247)}\sin(2\pi t)$$

where the knot points were at 01/02/1993 and 01/02/1994. The estimated linear trend decreased at the rate of 2.25cm/year. The simple linear regression is

$$x_t = 0.4536 - 0.0181t,$$

giving the estimated rate of decrease of 1.24cm/year. The S+ output is below.

```
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/02/1993
2: 01/02/1994
3:
ky= 33.0246575342466 34.0246575342466

Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept)  0.5958  0.3422     1.7412  0.0865
        slope.1 -0.0225  0.0098    -2.2848  0.0257
amplitude.sin.1 -0.1475  0.0487    -3.0296  0.0035
amplitude.sin.2  0.1563  0.0766     2.0407  0.0455
amplitude.sin.3 -0.2992  0.0661    -4.5239  0.0000
Overall Corrected AIC=-2.79789153967207


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  0.4536  0.5296     0.8564  0.3949
sample.year -0.0181  0.0152    -1.1892  0.2386
Corrected AIC for simple linear regression=-1.94287173093504
```


Threshold regression
Linear trend from threshold regression
Simple regression
Knot point
Depth (m)
0.2
0.0
-0.2
-0.4
-0.6
29/04/1992
29/04/1994
29/04/1996
29/04/1998
Date

(24) DC16M. There are 67 observations. The final model is given by

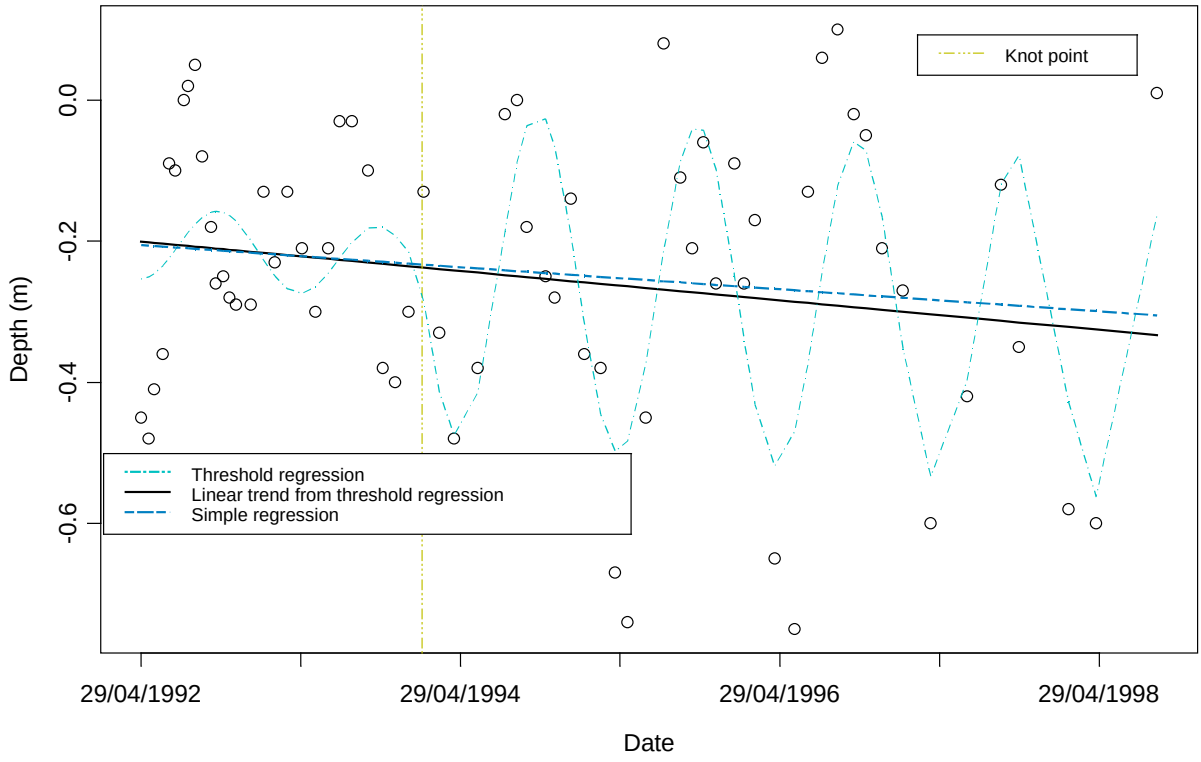
$$x_t = 0.4707 - 0.0208\,t - 0.0530\sin(2\pi t) - 0.1842\,\delta_{(t-34.0247)}\sin(2\pi t)$$

where the knot point was at 01/02/1994. The estimated linear trend decreased at the rate of 2.08cm/year. The simple linear regression is

$$x_t = 0.2991 - 0.0156\,t,$$

giving the estimated rate of decrease of 1.56cm/year. The S+ output is below.

```
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/02/1994
2:
ky= 34.0246575342466

Coefficients:
                 Value Std. Error t value Pr(>|t|)
    (Intercept)  0.4707  0.3760     1.2517  0.2153
        slope.1 -0.0208  0.0108    -1.9233  0.0590
amplitude.sin.1 -0.0530  0.0413    -1.2834  0.2040
amplitude.sin.2 -0.1842  0.0540    -3.4119  0.0011

Overall Corrected AIC=-2.61291360415627


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  0.2991  0.4900     0.6106  0.5436
sample.year -0.0156  0.0141    -1.1100  0.2711
Corrected AIC for simple linear regression=-2.09839594942594
```


Knot point
Threshold regression
Linear trend from threshold regression
Simple regression
Depth (m)
0.0
-0.2
-0.4
-0.6
29/04/1992
29/04/1994
29/04/1996
29/04/1998
Date

(25) DC18I. There are 68 observations. The final model is given by

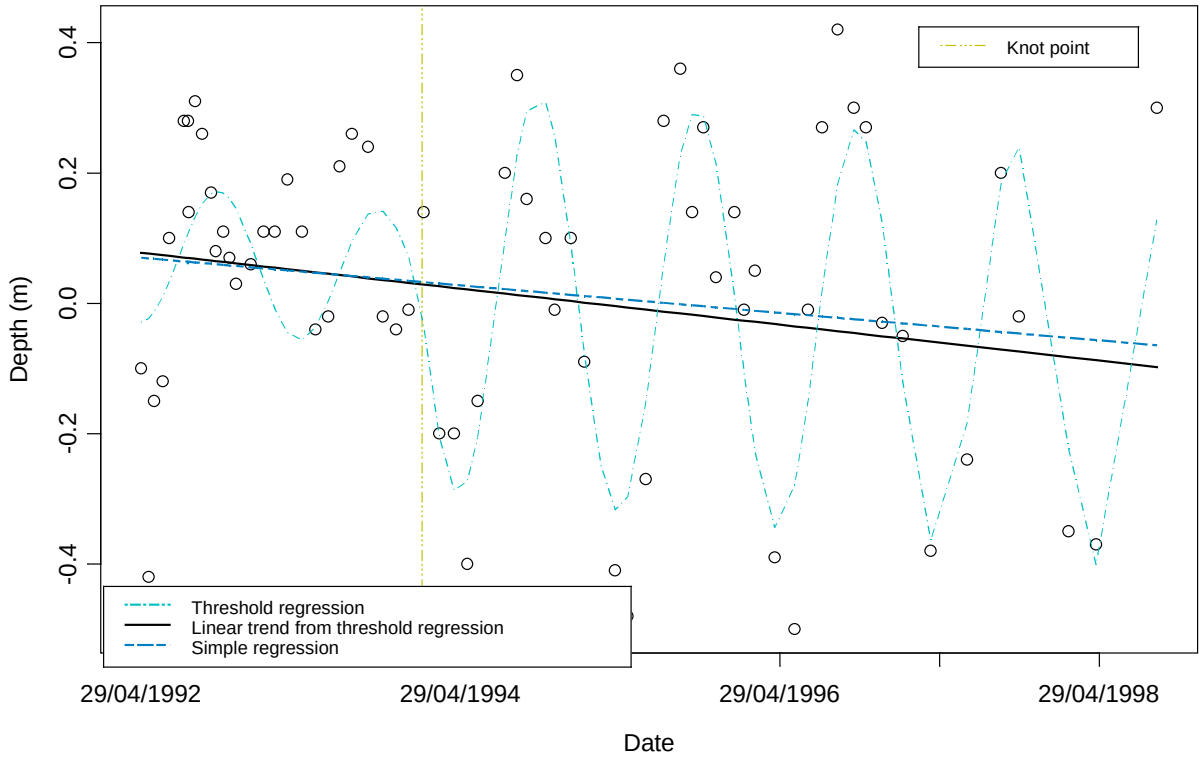
$$x_t = 0.9682 - 0.0276t - 0.1072\sin(2\pi t) - 0.2073\delta_{(t-34.0247)}\sin(2\pi t)$$

where the knot point was at 01/02/1994. The estimated linear trend decreased at the rate of 2.76cm/year. The simple linear regression is

$$x_t = 0.7512 - 0.0211t,$$

giving the estimated rate of decrease of 2.11cm/year. The S+ output is below.

```
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/02/1994
2:
ky= 34.0246575342466

Coefficients:
                 Value Std. Error t value Pr(>|t|)
    (Intercept)  0.9682  0.3652     2.6511  0.0101
        slope.1 -0.0276  0.0105    -2.6271  0.0108
amplitude.sin.1 -0.1072  0.0400    -2.6794  0.0094
amplitude.sin.2 -0.2073  0.0519    -3.9922  0.0002

Overall Corrected AIC=-2.67714025369124


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  0.7512  0.5697     1.3187  0.1918
sample.year -0.0211  0.0164    -1.2886  0.2021
Corrected AIC for simple linear regression=-1.79882832857705
```


Depth (m)
0.4
0.2
0.0
-0.2
-0.4
Knot point
Threshold regression
Linear trend from threshold regression
Simple regression
29/04/1992
29/04/1994
29/04/1996
29/04/1998
Date

(26) DC20M. There are 68 observations. The final model is given by

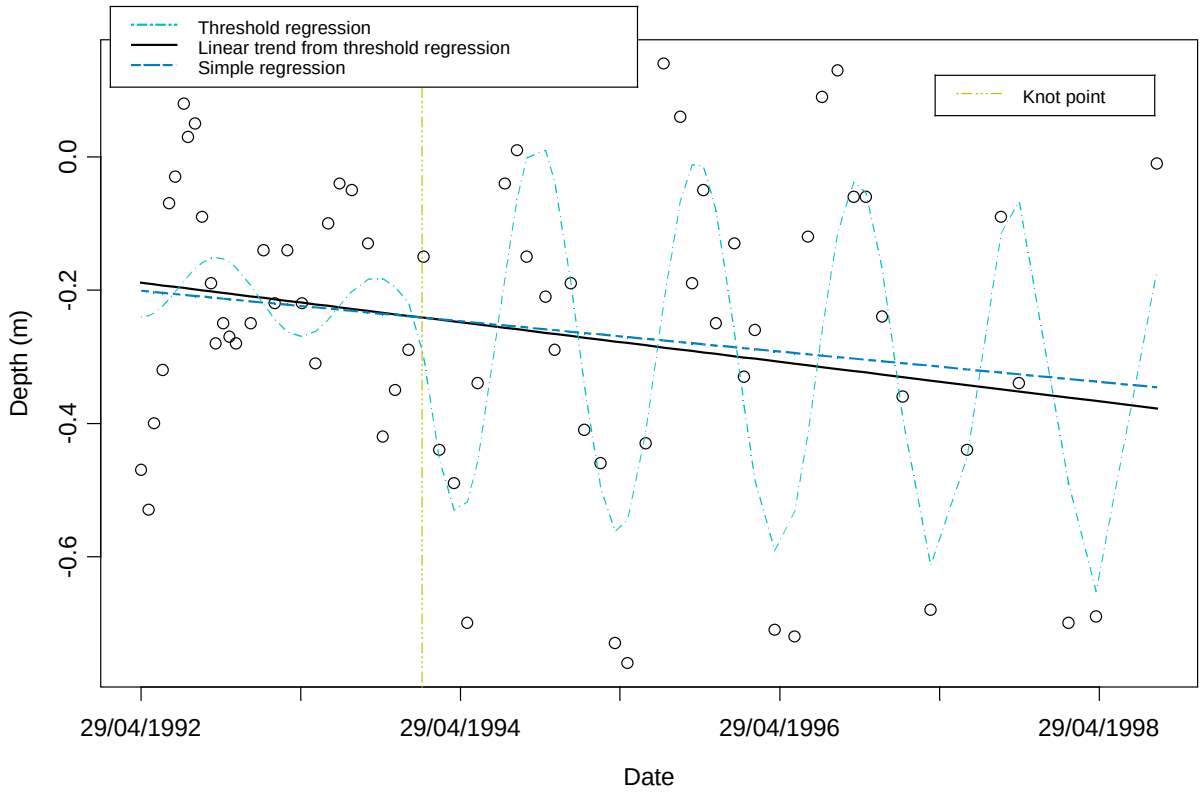
$$x_t = 0.7684 - 0.0297\,t - 0.0517\sin(2\pi t) - 0.2348\,\delta_{(t-34.0247)}\sin(2\pi t)$$

where the knot point was at 01/02/1994. The estimated linear trend decreased at the rate of 2.97cm/year. The simple linear regression is

$$x_t = 0.5339 - 0.0228\,t,$$

giving the estimated rate of decrease of 2.28cm/year. The S+ output is below.

```
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/02/1994
2:
ky= 34.0246575342466

Coefficients:
                 Value Std. Error t value Pr(>|t|)
    (Intercept)  0.7684  0.3934     1.9531  0.0552
        slope.1 -0.0297  0.0113    -2.6214  0.0109
amplitude.sin.1 -0.0517  0.0432    -1.1967  0.2358
amplitude.sin.2 -0.2348  0.0560    -4.1895  0.0001

Overall Corrected AIC=-2.52394518227042


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  0.5339  0.5504     0.9700  0.3356
sample.year -0.0228  0.0158    -1.4386  0.1550

Corrected AIC for simple linear regression=-1.86593820913597
```


Threshold regression
Linear trend from threshold regression
Simple regression
Knot point
Depth (m)
0.0
-0.2
-0.4
-0.6
29/04/1992
29/04/1994
29/04/1996
29/04/1998
Date

(27) DC22I. There are 68 observations. The final model is given by

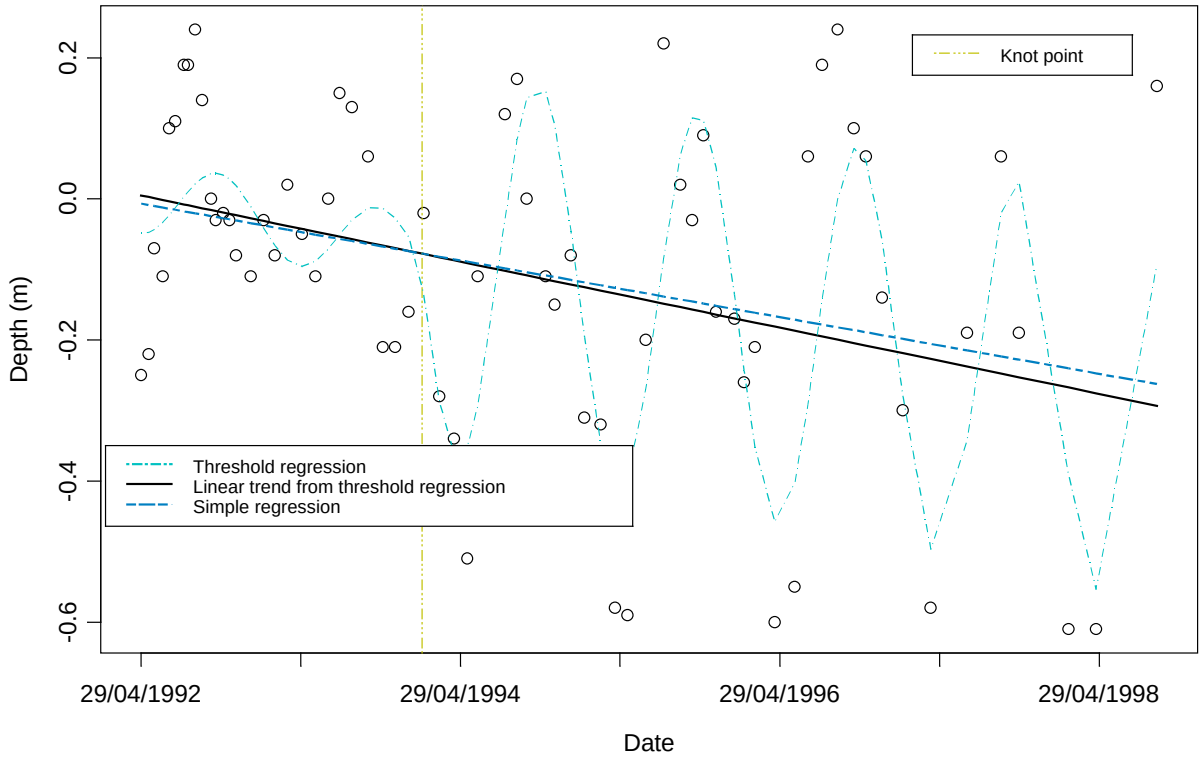
$$x_t = 1.5161 - 0.0468\,t - 0.0537\sin(2\pi t) - 0.2246\,\delta_{(t-34.0247)}\sin(2\pi t)$$

where the knot point was at 01/02/1994. The estimated linear trend decreased at the rate of 4.68cm/year. The simple linear regression is

$$x_t = 1.2896 - 0.0402\,t,$$

giving the estimated rate of decrease of 4.02cm/year. The S+ output is below.

```
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/02/1994
2:
ky= 34.0246575342466

Coefficients:
                 Value Std. Error t value Pr(>|t|)
    (Intercept)  1.5161  0.3688     4.1112  0.0001
        slope.1 -0.0468  0.0106    -4.4149  0.0000
amplitude.sin.1 -0.0537  0.0405    -1.3261  0.1895
amplitude.sin.2 -0.2246  0.0525    -4.2757  0.0001

Overall Corrected AIC=-2.65339581056223


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  1.2896  0.5260     2.4520  0.0169
sample.year -0.0402  0.0151    -2.6553  0.0099
Corrected AIC for simple linear regression=-1.95673855783856
```


Knot point
Threshold regression
Linear trend from threshold regression
Simple regression
Depth (m)
0.2
0.0
-0.2
-0.4
-0.6
29/04/1992
29/04/1994
29/04/1996
29/04/1998
Date

(28) DC26I. There are 68 observations. The final model is given by

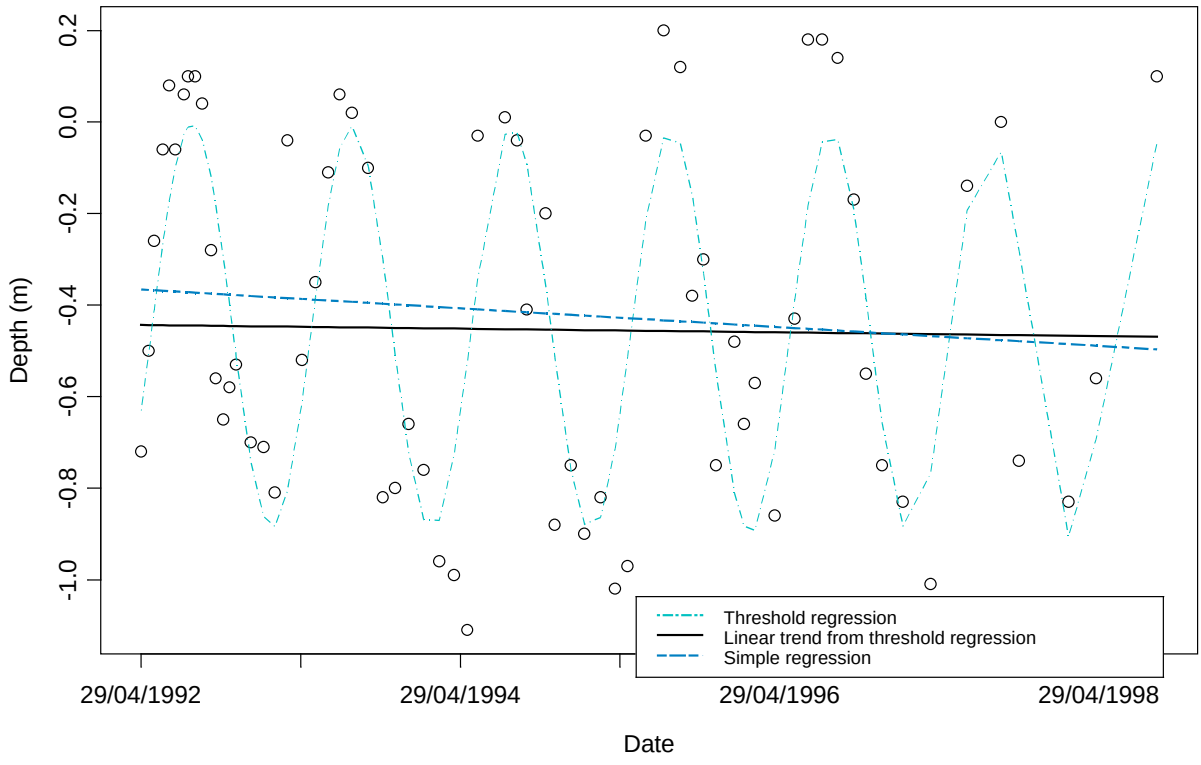
$$x_t = -0.3166 - 0.0040\,t - 0.4399\sin(2\pi t)$$

where the knot point was at 01/02/1994. The estimated linear trend decreased at the rate of 0.40cm/year (no trend). The simple linear regression is

$$x_t = 0.2802 - 0.0206\,t\,,$$

giving the estimated rate of decrease of 2.06cm/year. The S+ output is below.

```
Coefficients:
                  Value Std. Error  t value Pr(>|t|)
    (Intercept)  -0.3166   0.5592    -0.5663   0.5732
        slope.1  -0.0040   0.0165    -0.2447   0.8075
amplitude.sin.1  -0.4399   0.0415   -10.5992   0.0000
Overall Corrected AIC=-1.79284963675964

Coefficients:
             Value Std. Error t value Pr(>|t|)
(Intercept)  0.2802  0.9119     0.3072  0.7596
sample.year -0.0206  0.0269    -0.7648  0.4471
Corrected AIC for simple linear regression=-0.807568637028873
```



(29) DC28M. There are 68 observations. As an exception, we choose the end of each year as the starting point of periodic trend, which improves the results significantly. The starting time is 01/12/1960. The final model is given by

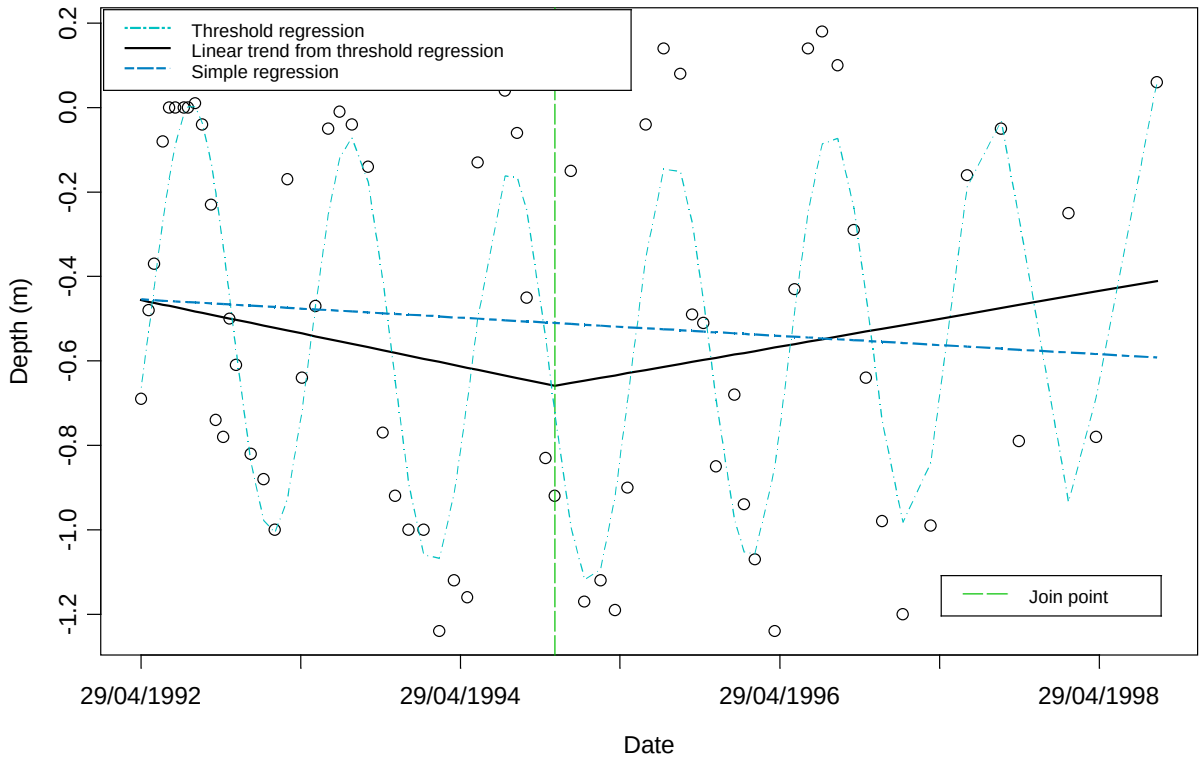
$$x_t = 2.0059 - 0.0783t + 0.1442(t - 34.0219)_+ - 0.4880\sin(2\pi t)$$

where the join point was at 01/12/1994. The estimated linear trend decreased at the rate of 7.83cm/year and then increases at 6.59cm/year. The simple linear regression is

$$x_t = 0.2255 - 0.0216\,t\,,$$

giving the estimated rate of decrease of 2.16cm/year. The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/12/1994
2:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1:
jy= 34.0219178082192

Coefficients:
                  Value Std. Error  t value Pr(>|t|)
    (Intercept)   2.0059   1.4246     1.4080   0.1640
        slope.1  -0.0783   0.0434    -1.8053   0.0757
        slope.2   0.1442   0.0748     1.9287   0.0582
amplitude.sin.1  -0.4880   0.0476   -10.2618   0.0000

Overall Corrected AIC=-1.5225051218987


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  0.2255  1.0452     0.2157  0.8299
sample.year -0.0216  0.0308    -0.7021  0.4851

Corrected AIC for simple linear regression=-0.534829569557052
```


Threshold regression
Linear trend from threshold regression
Simple regression
Join point
Depth (m)
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
29/04/1992
29/04/1994
29/04/1996
29/04/1998
Date

(30) DC34I. There are 64 observations. As an exception, we choose the beginning of each year as the starting point of periodic trend, which improves the results significantly. The starting time is 01/01/1960. The final model is given by

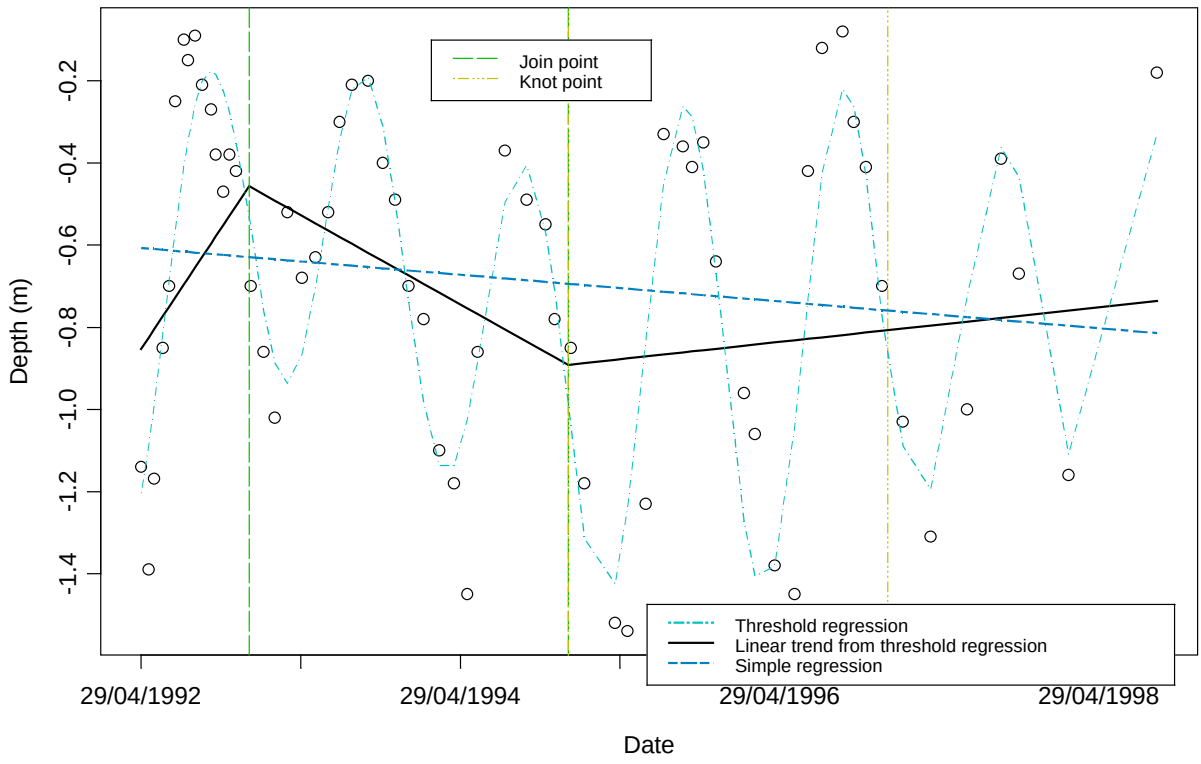
$$x_t = -19.8009 + 0.5858\,t - 0.8033(t - 33.0247)_+ + 0.2597(t - 35.0274)_+ \\ -0.4307\sin(2\pi t) - 0.1692\,\delta_{(t-35.0247)}\sin(2\pi t) + 0.1834\,\delta_{(t-37.0273)}\sin(2\pi t)$$

where the join point was at 01/01/1994, the knot point was at 01/01/1997. 01/01/1995 acted as both a join point and knot point. The estimated linear trend increased at the rate of 58.58cm/year, then decreased at 21.75cm/year and finally increased at 4.22cm/year. The simple linear regression is

$$x_t = 0.4438 - 0.0325\,t\,,$$

giving the estimated rate of decrease of 3.25cm/year. The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/01/1993
2: 01/01/1995
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/01/1995
2: 01/01/1997
3:
jy= 33.0246575342466 35.0246575342466
ky= 35.0246575342466 37.027397260274

Coefficients:
                  Value Std. Error  t value Pr(>|t|)
    (Intercept) -19.8009   5.8183    -3.4032   0.0012
        slope.1   0.5858   0.1775     3.2996   0.0017
        slope.2  -0.8033   0.2088    -3.8464   0.0003
        slope.3   0.2597   0.0725     3.5802   0.0007
amplitude.sin.1  -0.4307   0.0469    -9.1820   0.0000
amplitude.sin.2  -0.1692   0.0788    -2.1480   0.0360
amplitude.sin.3   0.1834   0.1096     1.6728   0.0999

Overall Corrected AIC=-2.09190332286477


Coefficients:
             Value Std. Error t value Pr(>|t|)
(Intercept)  0.4438  1.0300     0.4309  0.6680
sample.year -0.0325  0.0296    -1.0966  0.2771

Corrected AIC for simple linear regression=-0.67971114037612
```


Join point
Knot point
Threshold regression
Linear trend from threshold regression
Simple regression
Depth (m)
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
29/04/1992
29/04/1994
29/04/1996
29/04/1998
Date

(31) DC36M. There are 63 observations. The reading at 22/04/1998 was missing. As an exception, we choose March as the starting point of periodic trend, which improves the results significantly. The starting time is 01/03/1960. The final model is given by

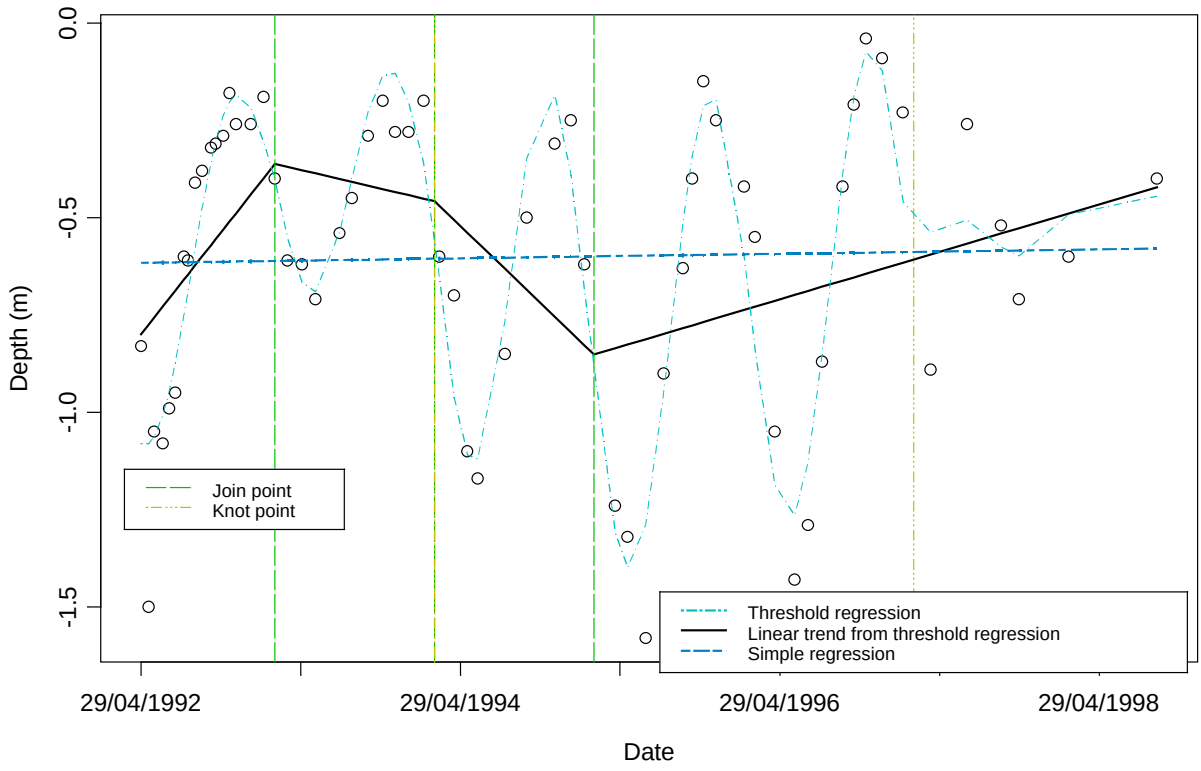
$$x_t = -17.5889 + 0.5217\,t - 0.6175(t-33.0219)_+ - 0.2981(t-34.0219)_+ + 0.5158(t-35.0219)_+ \\ -0.3083\sin(2\pi t) - 0.2618\delta_{(t-34.0219)}\sin(2\pi t) + 0.6543\delta_{(t-37.0247)}\sin(2\pi t)$$

where the join points were at 01/03/1993 and 01/03/1995, the knot point was at 01/03/1997. 01/03/1994 acted as both a join point and knot point. The estimated linear trend increased at the rate 52.17cm/year, then decreased at 9.58cm/year and 39.39cm/year, and finally increased at 12.19cm/year. The simple linear regression is

$$x_t = -0.8017 + 0.0058\,t,$$

giving the estimated rate of decrease of 0.58cm/year (no trend). The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/03/1993
2: 01/03/1994
3: 01/03/1995
4:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/03/1994
2: 01/03/1997
3:
jy= 33.0219178082192 34.0219178082192 35.0219178082192
ky= 34.0219178082192 37.0246575342466

Coefficients:
                   Value Std. Error  t value Pr(>|t|)
    (Intercept) -17.5899   4.0762    -4.3152   0.0001
        slope.1   0.5217   0.1249     4.1763   0.0001
        slope.2  -0.6175   0.1966    -3.1417   0.0027
        slope.3  -0.2981   0.1595    -1.8688   0.0671
        slope.4   0.5158   0.1026     5.0261   0.0000
amplitude.sin.1  -0.3083   0.0413    -7.4670   0.0000
amplitude.sin.2  -0.2681   0.0578    -4.6420   0.0000
amplitude.sin.3   0.6543   0.1049     6.2360   0.0000

Overall Corrected AIC=-2.65011255762925


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -0.8017  0.9641    -0.8315  0.4090
sample.year  0.0058  0.0279     0.2071  0.8366

Corrected AIC for simple linear regression=-0.808043672316406
```


0.0
-0.5
-1.0
-1.5
Depth (m)
Join point
Knot point
Threshold regression
Linear trend from threshold regression
Simple regression
29/04/1992
29/04/1994
29/04/1996
29/04/1998
Date

(32) DC38M. There are 65 observations. The reading at 22/04/1998 was missing. The final model is given by

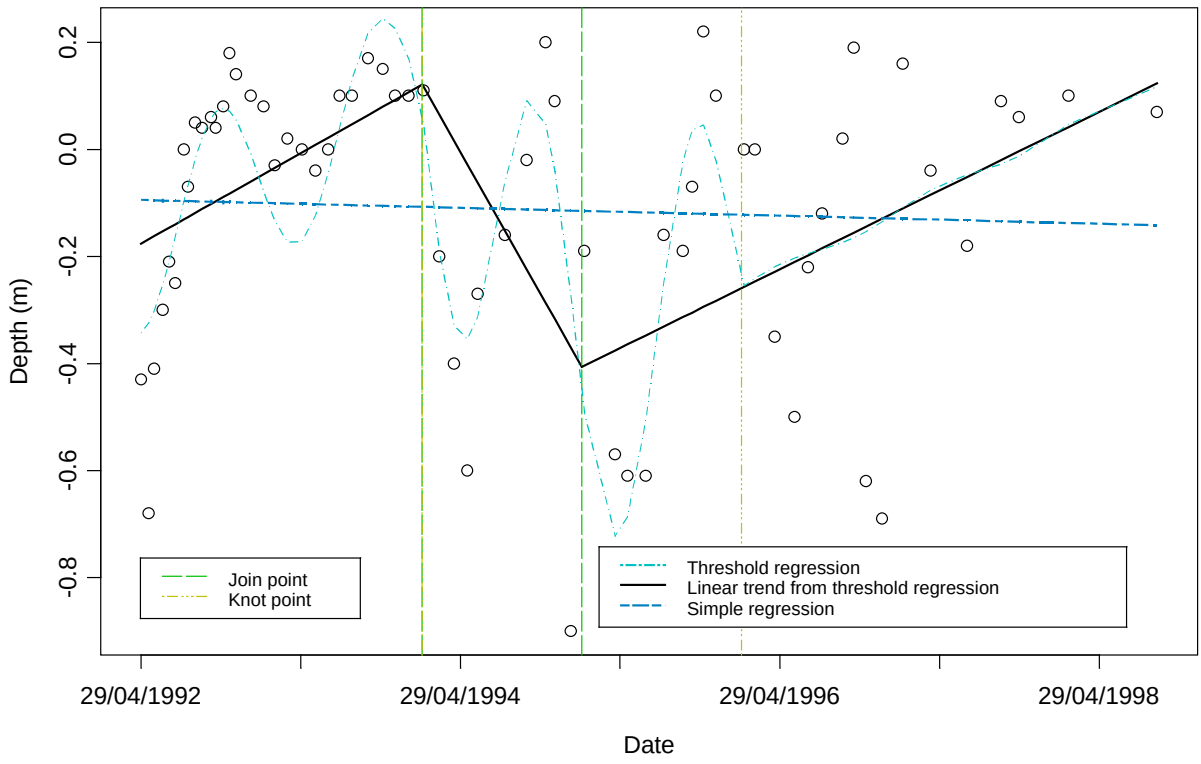
$$x_t = -5.6149 + 0.1686\,t - 0.6961(t - 34.0247)_+ + 0.6746(t - 35.0247)_+ \\ -0.1680\sin(2\pi t) - 0.1810\,\delta_{(t-34.0247)}\sin(2\pi t) + 0.3584\,\delta_{(t-36.0247)}\sin(2\pi t)$$

where the join point was at 01/02/1995, the knot point was at 01/02/1996. 01/02/1994 acted as both a join point and knot point. The estimated linear trend increased at the rate of 16.86cm/year, then decreased at 52.75cm/year and finally increased at 14.71cm/year. The simple linear regression is

$$x_t = 0.1438 - 0.0074\,t,$$

giving the estimated rate of decrease of 0.74cm/year (no trend). The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/02/1994
2: 01/02/1995
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/02/1994
2: 01/02/1996
3:
jy= 34.0246575342466 35.0246575342466
ky= 34.0246575342466 36.0246575342466

Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept) -5.6149  2.0473    -2.7426  0.0081
        slope.1  0.1686  0.0619     2.7227  0.0086
        slope.2 -0.6961  0.1519    -4.5817  0.0000
        slope.3  0.6746  0.1292     5.2203  0.0000
amplitude.sin.1 -0.1680  0.0524    -3.2029  0.0022
amplitude.sin.2 -0.1810  0.0832    -2.1759  0.0337
amplitude.sin.3  0.3584  0.0928     3.8630  0.0003

Overall Corrected AIC=-2.10848710553659


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  0.1438  0.6730     0.2137  0.8315
sample.year -0.0074  0.0194    -0.3806  0.7048
Corrected AIC for simple linear regression=-1.52599146851676
```


Depth (m)
0.2
0.0
-0.2
-0.4
-0.6
-0.8
29/04/1992
29/04/1994
29/04/1996
29/04/1998
Date
Join point
Knot point
Threshold regression
Linear trend from threshold regression
Simple regression

(33) DC39I. There are 65 observations. The reading at 22/04/1998 was missing. The final model is given by

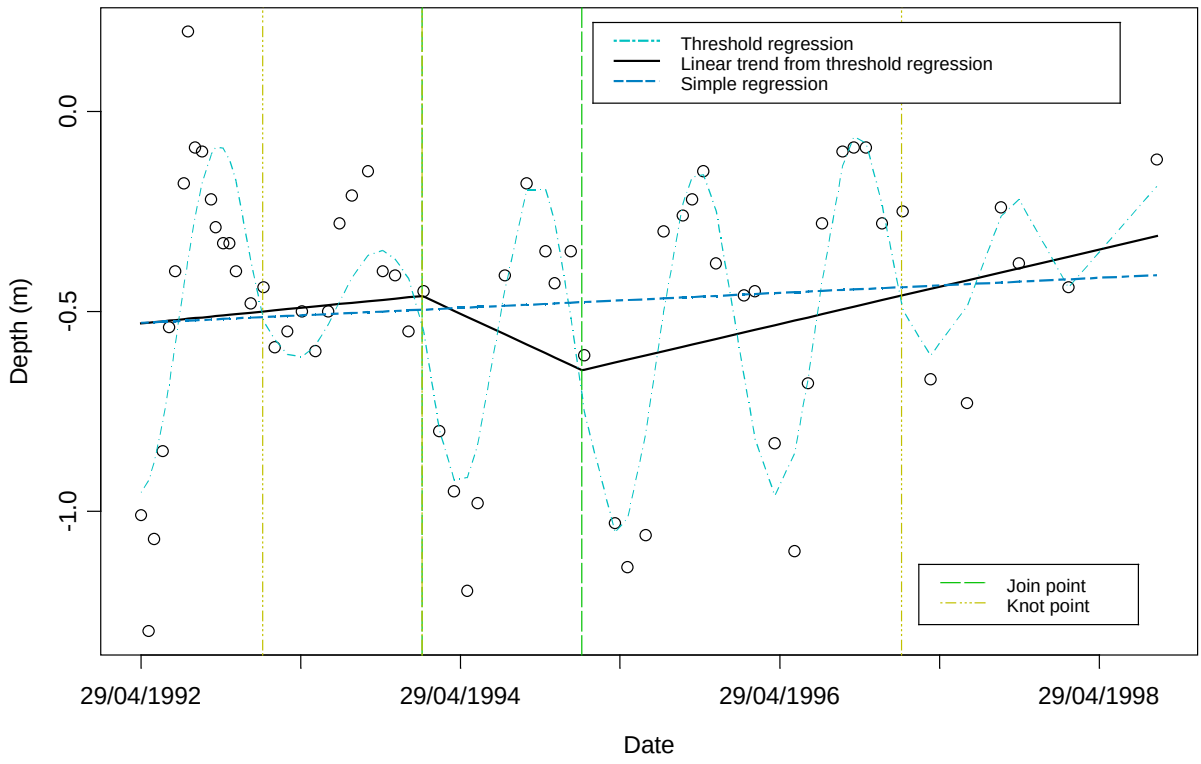
$$x_t = -1.7861 + 0.0389t - 0.2247(t - 34.0247)_+ + 0.2790(t - 35.0247)_+ \\ -0.4249\sin(2\pi t) + 0.3000\delta_{(t-33.0247)}\sin(2\pi t) - 0.3038\delta_{(t-34.0247)}\sin(2\pi t) + 0.2561\delta_{(t-37.0247)}\sin(2\pi t)$$

where the join point was at 01/02/1995, the knot points were at 01/02/1993 and 01/02/1997. 01/02/1994 acted as both a join point and knot point. The estimated linear trend increased at the rate of 3.89cm/year (no trend), then decreased at 21.58cm/year and finally increased at 6.32cm/year. The simple linear regression is

$$x_t = -1.1325 + 0.0187t,$$

giving the estimated rate of increase of 1.87cm/year (no trend). The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/02/1994
2: 01/02/1995
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/02/1993
2: 01/02/1994
3: 01/02/1997
4:
jy= 34.0246575342466 35.0246575342466
ky= 33.0246575342466 34.0246575342466 37.027397260274

Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept) -1.7861  1.9235    -0.9286  0.3571
        slope.1  0.0389  0.0581     0.6696  0.5058
        slope.2 -0.2247  0.1400    -1.6052  0.1141
        slope.3  0.2790  0.1179     2.3661  0.0215
amplitude.sin.1 -0.4249  0.0630    -6.7460  0.0000
amplitude.sin.2  0.3000  0.0994     3.0168  0.0038
amplitude.sin.3 -0.3038  0.0920    -3.3012  0.0017
amplitude.sin.4  0.2561  0.1093     2.3436  0.0227

Overall Corrected AIC=-2.21403696231329


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -1.1325  0.8136    -1.3919  0.1689
sample.year  0.0187  0.0235     0.7974  0.4283

Corrected AIC for simple linear regression=-1.14640835358799
```


Threshold regression
Linear trend from threshold regression
Simple regression
Join point
Knot point
Depth (m)
0.0
-0.5
-1.0
29/04/1992
29/04/1994
29/04/1996
29/04/1998
Date

(34) DC40D. There are 62 observations. The reading at 22/04/1998 was missing. The final model is given by

$$\begin{aligned} x_t = & -83.7824 + 2.1306t - 1.0987(t-33.0247)_+ + 2.7029(t-36.0247)_+ \\ & -4.3178(t-37.0247)_+ + 3.8600(t-38.0247)_+ \\ & -0.2281\delta_{(t-34.0247)}\sin(2\pi t) - 0.4815\delta_{(t-35.0247)}\sin(2\pi t) + 0.2561\delta_{(t-37.0247)}\sin(2\pi t) \end{aligned}$$

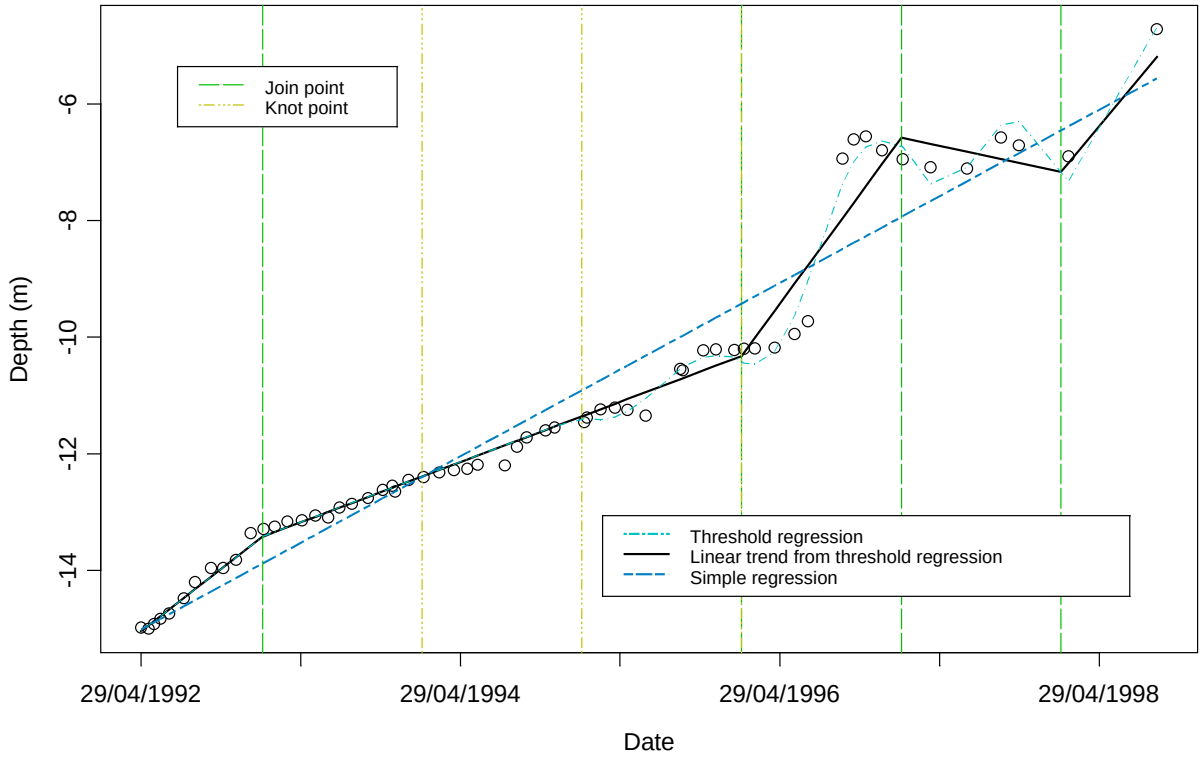
where the join points were at 01/02/1993, 01/02/1997 and 01/02/1998, the knot points were at 01/02/1994 and 01/02/1995. 01/02/1996 acted as both a join point and knot point. The estimated linear trend increased at the rate of 213.06cm/year, 103.19cm/year, 310.48cm/year, then decreased at 121.30cm/year and finally increased at 264.70cm/year. The simple linear regression is

$$x_t = -62.9112 + 1.4847t,$$

giving the estimated rate of increase of 148.47cm/year (no trend). The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/02/1993
2: 01/02/1996
3: 01/02/1997
4: 01/02/1998
5:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/02/1994
2: 01/02/1995
3: 01/02/1996
4:
jy=     33.0246575342466     36.0246575342466     37.027397260274
38.027397260274
ky= 34.0246575342466 35.0246575342466 36.0246575342466
Please provide  4  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 0
2: 0
3: 1
4: 1
5:

Coefficients:
                  Value Std. Error  t value Pr(>|t|)
    (Intercept) -83.7824   5.1319   -16.3259   0.0000
        slope.1   2.1306   0.1565    13.6107   0.0000
        slope.2  -1.0987   0.1770    -6.2068   0.0000
        slope.3   2.7029   0.1506    17.9488   0.0000
        slope.4  -4.3178   0.2973   -14.5217   0.0000
        slope.5   3.8600   0.5724     6.7432   0.0000
amplitude.sin.2  -0.2281   0.0859    -2.6536   0.0105
```

```
amplitude.sin.3  -0.4815   0.1144    -4.2105   0.0001

Overall Corrected AIC=-1.97245477556923


Coefficients:
                Value Std. Error  t value Pr(>|t|)
(Intercept) -62.9112   1.7201   -36.5750   0.0000
sample.year   1.4847   0.0494    30.0402   0.0000

Corrected AIC for simple linear regression=0.224941360066238
```

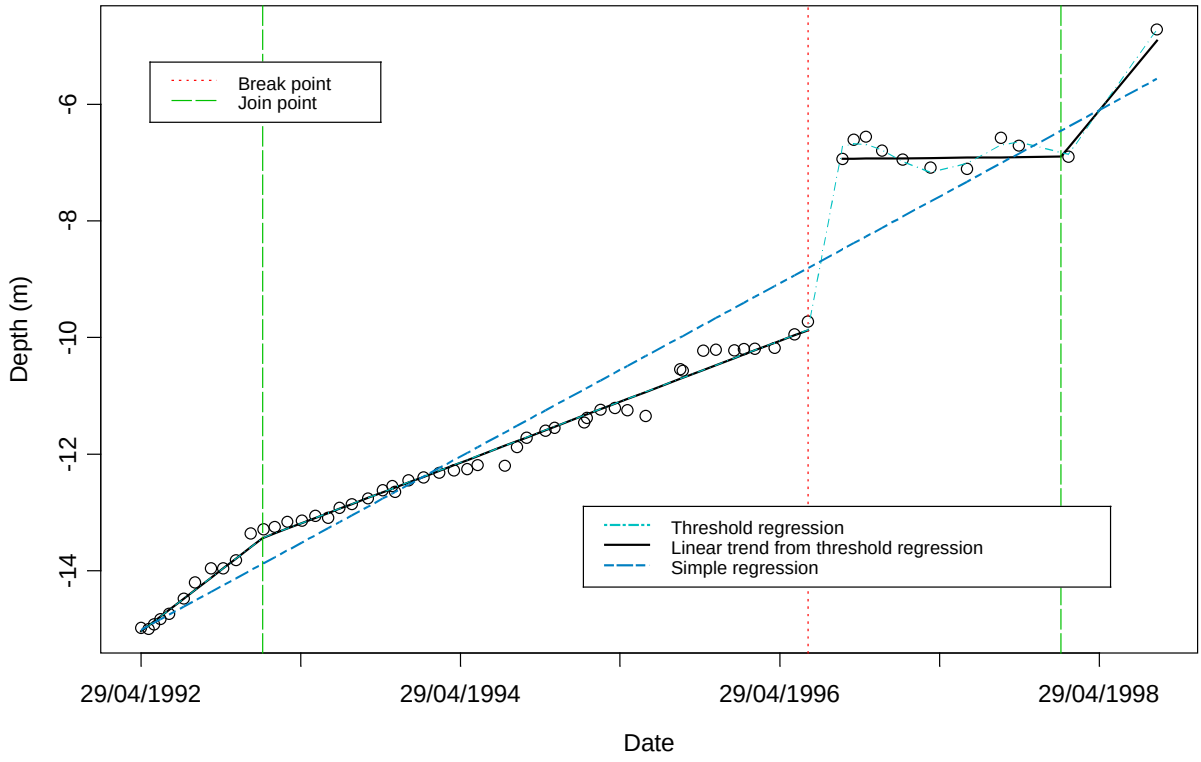


For a comparison, we also fit the following model:

$$x_t = \begin{cases} -82.7585 + 2.0991t - 1.0555(t - 33.0247)_+ & \text{if} \quad t \le 36.4411 \\ -7.9606 - 0.0279t + 3.2875(t - 38.0247)_+ - 0.2591\sin(2\pi t) & \text{if} \quad t > 36.4411 \end{cases}$$

```
input break dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A break date is a date at which all the trend changes)
1: 02/07/1996
2:
by= 36.441095890411
The program is now in the interactive graphic mode
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
```

```
1: 01/02/1993
2:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1:
jy= 33.0246575342466
Please provide  1  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 0
2:

Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept) -82.7585   3.4073   -24.2885   0.0000
    slope.1   2.0991   0.1039    20.2021   0.0000
    slope.2  -1.0555   0.1159    -9.1099   0.0000

input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/02/1998
2:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1:
jy= 38.027397260274
Please provide  1  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2:

Coefficients:
                  Value Std. Error  t value Pr(>|t|)
    (Intercept)  -7.9606   3.4847    -2.2844   0.0563
        slope.1   0.0279   0.0935     0.2988   0.7738
        slope.2   3.2875   0.3253    10.1059   0.0000
amplitude.sin.1  -0.2591   0.0586    -4.4191   0.0031

Overall Corrected AIC=-2.81424641527606
```


Break point
Join point
Threshold regression
Linear trend from threshold regression
Simple regression
Depth (m)
-6
-8
-10
-12
-14
29/04/1992
29/04/1994
29/04/1996
29/04/1998
Date

(35) DC41I. There are 64 observations. The reading at 22/04/1998 was missing. The final model is given by

$$x_t = 9.2673 - 0.3962\,t + 0.3093(t - 34.0247)_+ \\ -0.4442\sin(2\pi t) + 0.7446\delta_{(t-36.0247)}\sin(2\pi t) + 0.6913\delta_{(t-37.0247)}\sin(2\pi t)$$

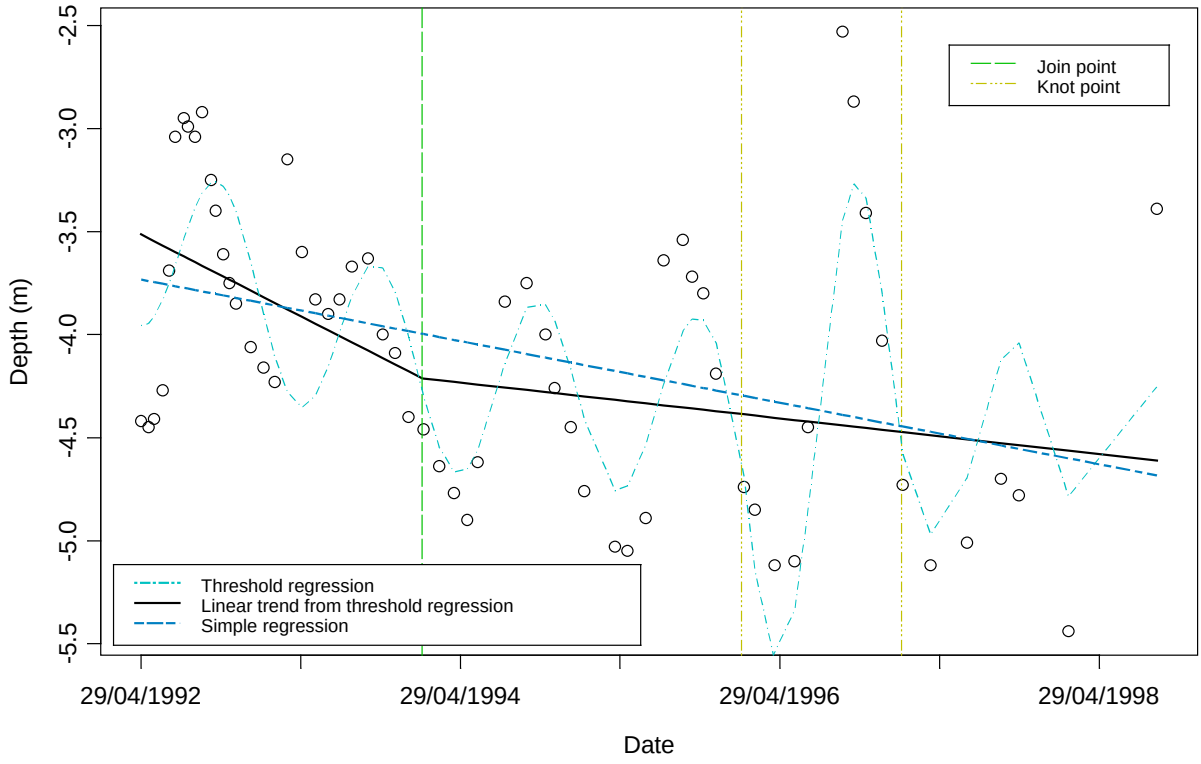
where the join point was at 01/02/1994, the knot points were at 01/02/1996 and 01/02/1997. The estimated linear trend increased at the rate of 39.62/year and 8.69cm/year. The simple linear regression is

$$x_t = 1.0862 - 0.1494\,t\,,$$

giving the estimated rate of increase of 148.47cm/year (no trend). The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/02/1994
2:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/02/1996
2: 01/02/1997
3:
jy= 34.0246575342466
ky= 36.0246575342466 37.027397260274
Please provide  3  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2: 1
3: 1
4:

Coefficients:
                 Value Std. Error t value Pr(>|t|)
    (Intercept)  9.2673  3.6876     2.5131  0.0148
        slope.1 -0.3962  0.1109    -3.5721  0.0007
        slope.2  0.3093  0.1501     2.0608  0.0439
amplitude.sin.1 -0.4442  0.0867    -5.1225  0.0000
amplitude.sin.2 -0.7446  0.2120    -3.5127  0.0009
amplitude.sin.3  0.6913  0.3011     2.2959  0.0254

Overall Corrected AIC=-0.520772409335174


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  1.0862  1.5905     0.6829  0.4972
sample.year -0.1494  0.0459    -3.2536  0.0019
```

Corrected AIC for simple linear regression=0.178402056548536



(36) DC43I. There are 62 observations. The final model is given by

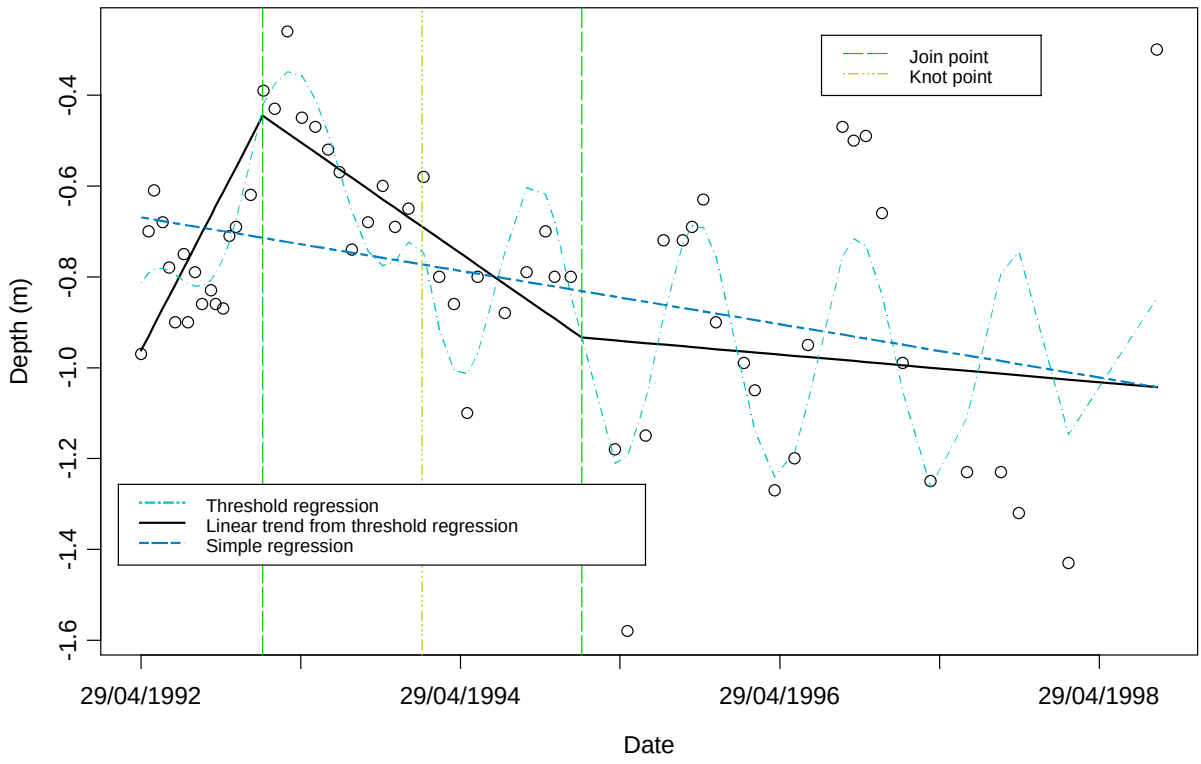
$$x_t = -22.8481 + 0.6784\,t - 0.9226(t - 33.0247)_+ + 0.2140(t - 35.0247)_+ \\ +0.1488\sin(2\pi t) - 0.4208\,\delta_{(t-34.0247)}\sin(2\pi t)$$

where the join points were at 01/02/1993 and 01/02/1995, the knot point was at 01/02/1994. The estimated linear trend increased at the rate of 67.84/year and then decreased at 24.42cm/year and 3.03cm/year. The simple linear regression is

$$x_t = 1.2239 - 0.0587\,t,$$

giving the estimated rate of increase of 5.87cm/year (no trend). The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/02/1993
2: 01/02/1995
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/02/1994
2:
jy= 33.0246575342466 35.0246575342466
ky= 34.0246575342466
Please provide  2  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2: 1
3:

Coefficients:
                  Value Std. Error  t value Pr(>|t|)
    (Intercept) -22.8481   4.6991    -4.8622   0.0000
        slope.1   0.6784   0.1436     4.7236   0.0000
        slope.2  -0.9226   0.1745    -5.2879   0.0000
        slope.3   0.2140   0.0685     3.1234   0.0028
amplitude.sin.1   0.1488   0.0483     3.0831   0.0032
amplitude.sin.2  -0.4208   0.0639    -6.5861   0.0000

Overall Corrected AIC=-2.30765361367905

Coefficients:
             Value Std. Error t value Pr(>|t|)
(Intercept)  1.2239  0.6472     1.8910  0.0635
sample.year -0.0587  0.0187    -3.1406  0.0026

Corrected AIC for simple linear regression=-1.61900098669982
```


Join point
Knot point
Threshold regression
Linear trend from threshold regression
Simple regression
Depth (m)
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
29/04/1992
29/04/1994
29/04/1996
29/04/1998
Date

(37) DC44S. There are 64 observations. The reading at 22/04/1998 was missing. The final model is given by

$$x_t = 1.5752 - 0.0546\,t - 0.2120(t - 33.0219)_+ + 0.4244(t - 34.0219)_+ - 0.2579(t - 35.0219)_+ \\ -0.1824\sin(2\pi t) + 0.2421\delta_{(t-33.0219)}\sin(2\pi t)$$

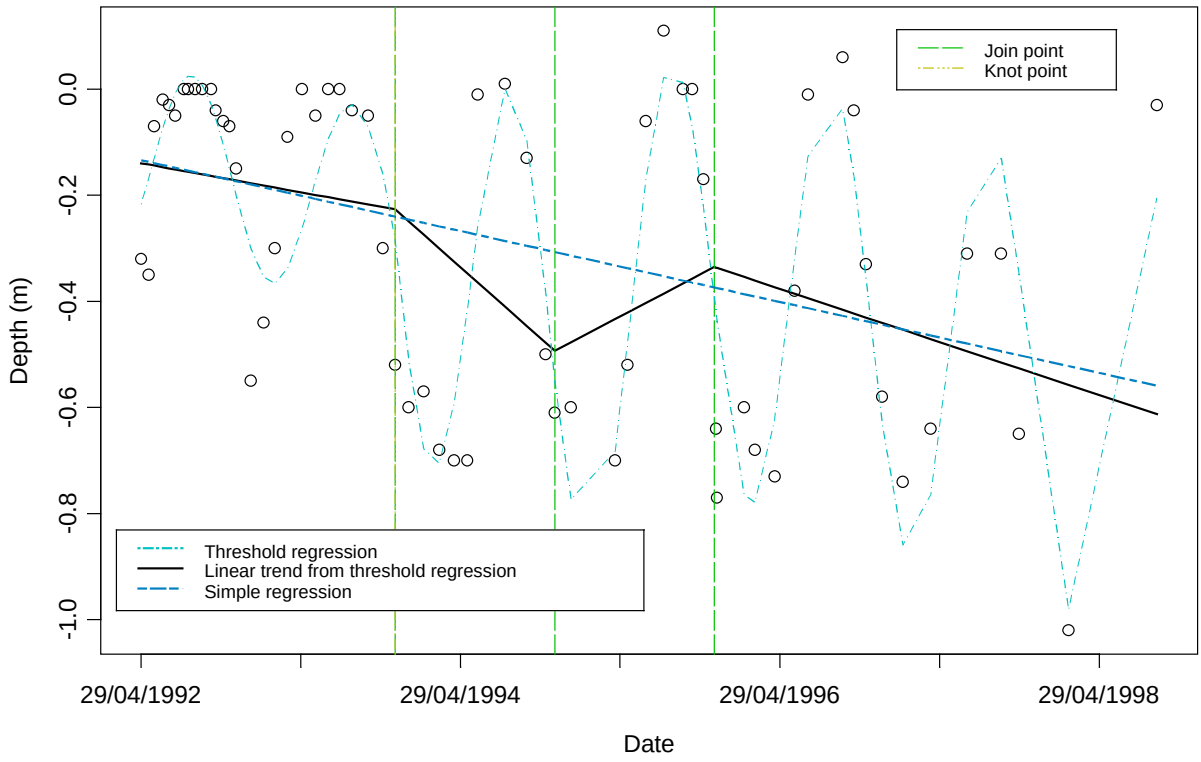
where the join points were at 01/12/1994 and 01/12/1995, 01/12/1993 acted as both join and knot points. The estimated linear trend decreased at the rate of 5.46cm/year and 26.66cm/year, and then increased at 15.78cm/year and finally decreased at 10.01cm/year. The simple linear regression is

$$x_t = 1.9641 - 0.0668\,t\,,$$

giving the estimated rate of increase of 6.68cm/year (no trend). The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/12/1993
2: 01/12/1994
3: 01/12/1995
4:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/12/1993
2:
jy= 33.0219178082192 34.0219178082192 35.0219178082192
ky= 33.0219178082192
Please provide  2  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2: 1
3:

Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept)  1.5752  1.5890     0.9913  0.3258
        slope.1 -0.0546  0.0494    -1.1056  0.2736
        slope.2 -0.2120  0.1238    -1.7124  0.0924
        slope.3  0.4244  0.1571     2.7010  0.0091
        slope.4 -0.2579  0.1071    -2.4091  0.0193
amplitude.sin.1 -0.1824  0.0425    -4.2863  0.0001
amplitude.sin.2 -0.2421  0.0555    -4.3595  0.0001

Overall Corrected AIC=-2.78146741619781


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  1.9641  0.6637     2.9592  0.0044
sample.year -0.0668  0.0196    -3.4021  0.0012
```

Corrected AIC for simple linear regression=-1.5143085064125



(38) DC45I. There are 63 observations. The reading at 22/04/1998 was missing. The final model is given by

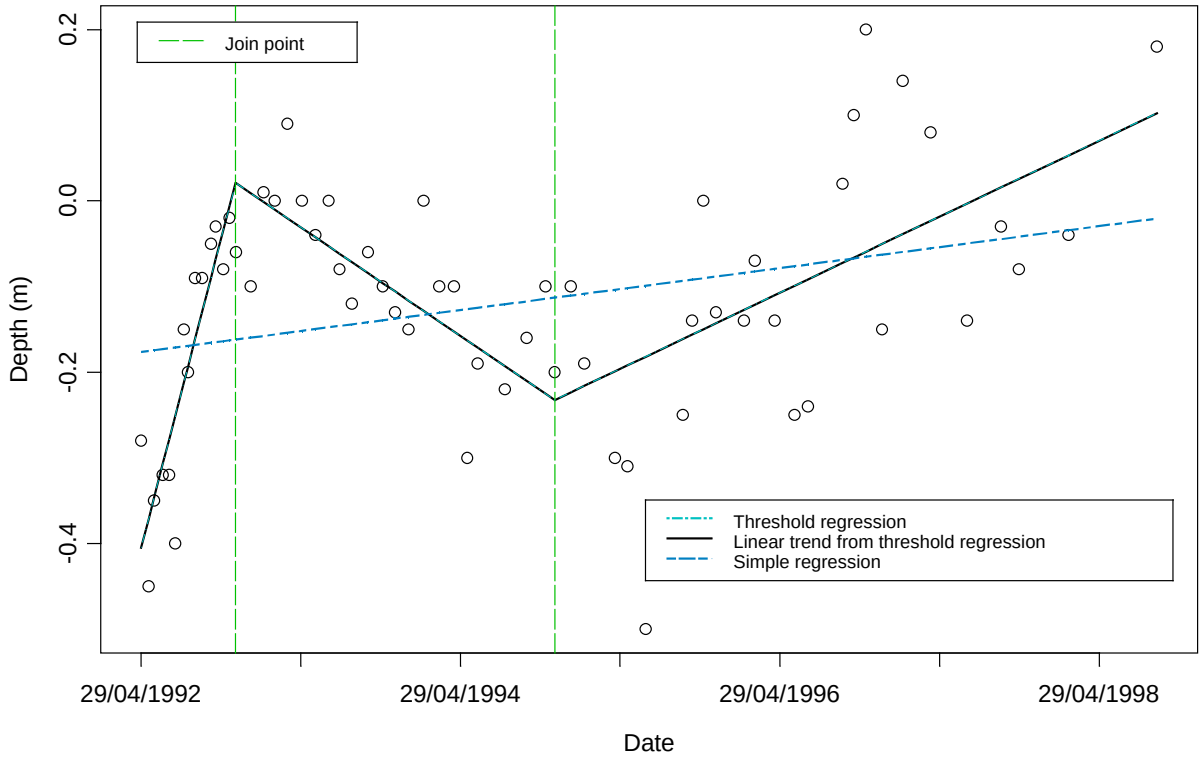
$$x_t = -23.0318 + 0.7199\,t - 0.8467(t - 32.0219)_+ + 0.2155(t - 34.0219)_+$$

where the join points were at 01/12/1992 and 01/12/1994. The estimated linear trend increased at the rate of 71.99cm/year ,then decreased at 12.62cm/year and finally increased at 8.97cm/year. The simple linear regression is

$$x_t = -0.9450 + 0.0245t\,,$$

giving the estimated rate of increase of 2.45cm/year (no trend). The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/12/1992
2: 01/12/1994
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1:
jy= 32.0219178082192 34.0219178082192
Please provide  1  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 0
2:

Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept) -23.0318   3.3922    -6.7896   0.0000
    slope.1   0.7199   0.1066     6.7527   0.0000
    slope.2  -0.8467   0.1219    -6.9477   0.0000
    slope.3   0.2155   0.0363     5.9395   0.0000

Overall Corrected AIC=-3.48596168040148


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -0.9450  0.3356    -2.8162  0.0066
sample.year  0.0245  0.0099     2.4629  0.0167
Corrected AIC for simple linear regression=-2.88733437407048
```


Join point
Threshold regression
Linear trend from threshold regression
Simple regression
Depth (m)
0.2
0.0
-0.2
-0.4
29/04/1992
29/04/1994
29/04/1996
29/04/1998
Date

(39) DC46I. There are 53 observations. The reading at 22/04/1998 was missing. The starting point is at 01/01/1960. The final model is given by

$$x_t = 7.7059 - 0.2208t + 0.2387(t - 34.0247)_+ + 0.3953(t - 36.0247)_+ - 1.3063(t - 37.0247)_+ \\ -0.4359\sin(2\pi t) - 0.2255\delta_{(t-35.0247)}\sin(2\pi t) + 0.2750\delta_{(t-36.0247)}\sin(2\pi t) - 0.4452\delta_{(t-37.0247)}\sin(2\pi t)$$

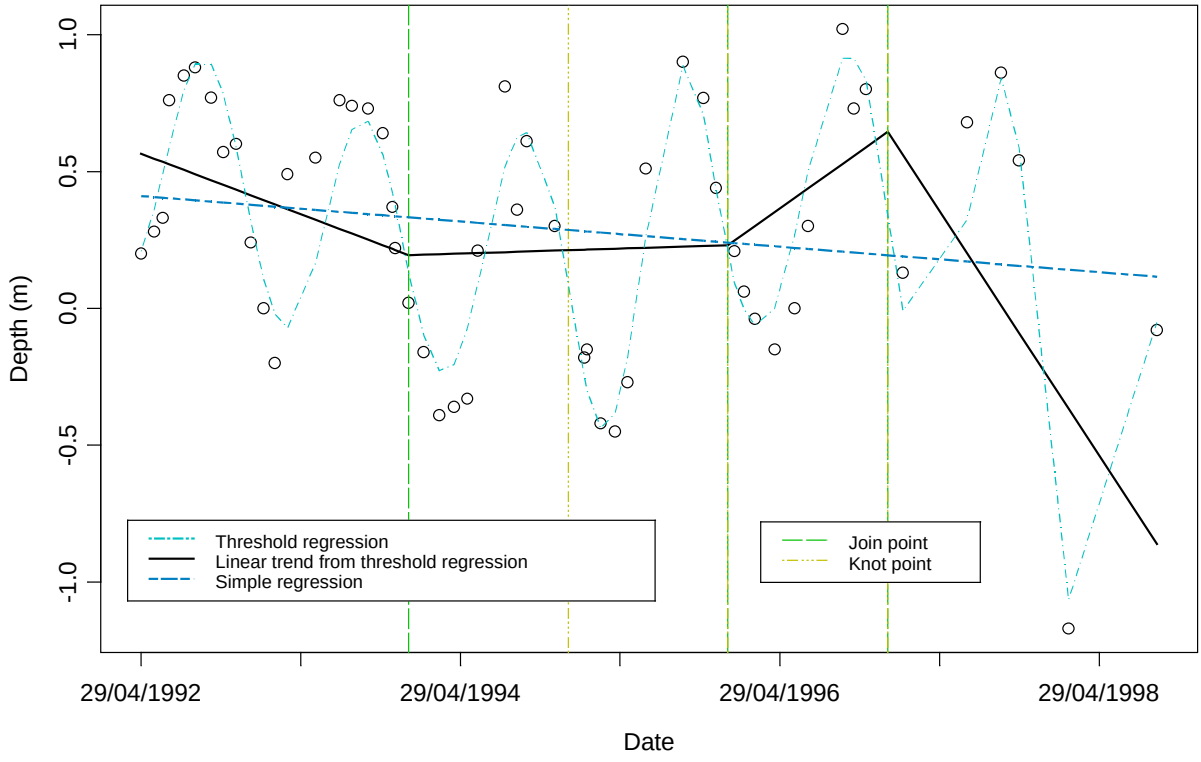
where the join point was at 01/01/1994, the knot point was at 01/01/1995. 01/01/1996 and 01/01/1997 acted as join and knot points. The estimated linear trend decreased at the rate of 22.08cm/year, then increased at 1.79cm/year 41.32cm/year, and finally decreased at 89.31cm/year. The simple linear regression is

$$x_t = 1.9058 - 0.0463t,$$

giving the estimated rate of increase of 4.63cm/year (no trend). The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/01/1994
2: 01/01/1996
3: 01/01/1997
4:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/01/1995
2: 01/01/1996
3: 01/01/1997
4:
jy= 34.0246575342466 36.0246575342466 37.027397260274
ky= 35.0246575342466 36.0246575342466 37.027397260274
Please provide  4  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2: 1
3: 1
4: 1
5:

Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept)  7.7059  2.0341     3.7883  0.0004
        slope.1 -0.2208  0.0610    -3.6169  0.0008
        slope.2  0.2387  0.1007     2.3699  0.0221
        slope.3  0.3953  0.1877     2.1062  0.0408
        slope.4 -1.3063  0.2579    -5.0659  0.0000
amplitude.sin.1 -0.4359  0.0483    -9.0259  0.0000
amplitude.sin.2 -0.2255  0.0977    -2.3093  0.0256
amplitude.sin.3  0.2750  0.1282     2.1446  0.0374
amplitude.sin.4 -0.4452  0.1494    -2.9794  0.0046
```

```
Overall Corrected AIC=-2.11173920152474


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  1.9058  1.2931     1.4738  0.1466
sample.year -0.0463  0.0371    -1.2477  0.2177

Corrected AIC for simple linear regression=-0.4704454744525
```

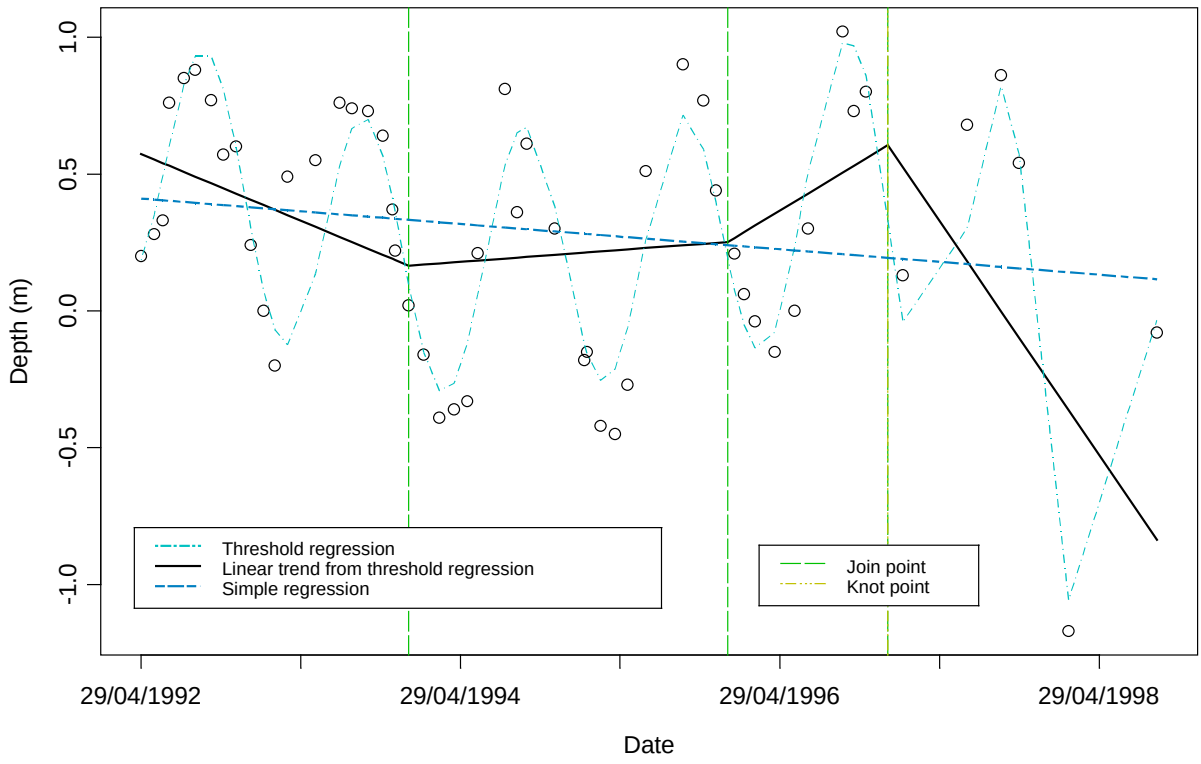


For comparison, we also fit the following model:

$$x_t = 8.4439 - 0.2433t + 0.2867(t - 34.0247)_+ + 0.3091(t - 36.0247)_+ - 1.2083(t - 37.0247)_+ - 0.4756\sin(2\pi t) - 0.3502\delta_{(t-37.0247)}\sin(2\pi t)$$

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/01/1994
2: 01/01/1996
3: 01/01/1997
4:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
```

```
1: 01/01/1997
2:
jy= 34.0246575342466 36.0246575342466 37.027397260274
ky= 37.027397260274
Please provide  2  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2: 1
3:

Coefficients:
                  Value Std. Error  t value Pr(>|t|)
    (Intercept)   8.4439   2.1016     4.0179   0.0002
        slope.1  -0.2433   0.0630    -3.8602   0.0003
        slope.2   0.2867   0.1015     2.8258   0.0069
        slope.3   0.3091   0.1723     1.7946   0.0792
        slope.4  -1.2083   0.2428    -4.9774   0.0000
amplitude.sin.1  -0.4756   0.0400   -11.8992   0.0000
amplitude.sin.2  -0.3502   0.1190    -2.9425   0.0050

Overall Corrected AIC=-2.08792429559528


Coefficients:
             Value Std. Error t value Pr(>|t|)
(Intercept)  1.9058  1.2931     1.4738  0.1466
sample.year -0.0463  0.0371    -1.2477  0.2177
Corrected AIC for simple linear regression=-0.4704454744525
```

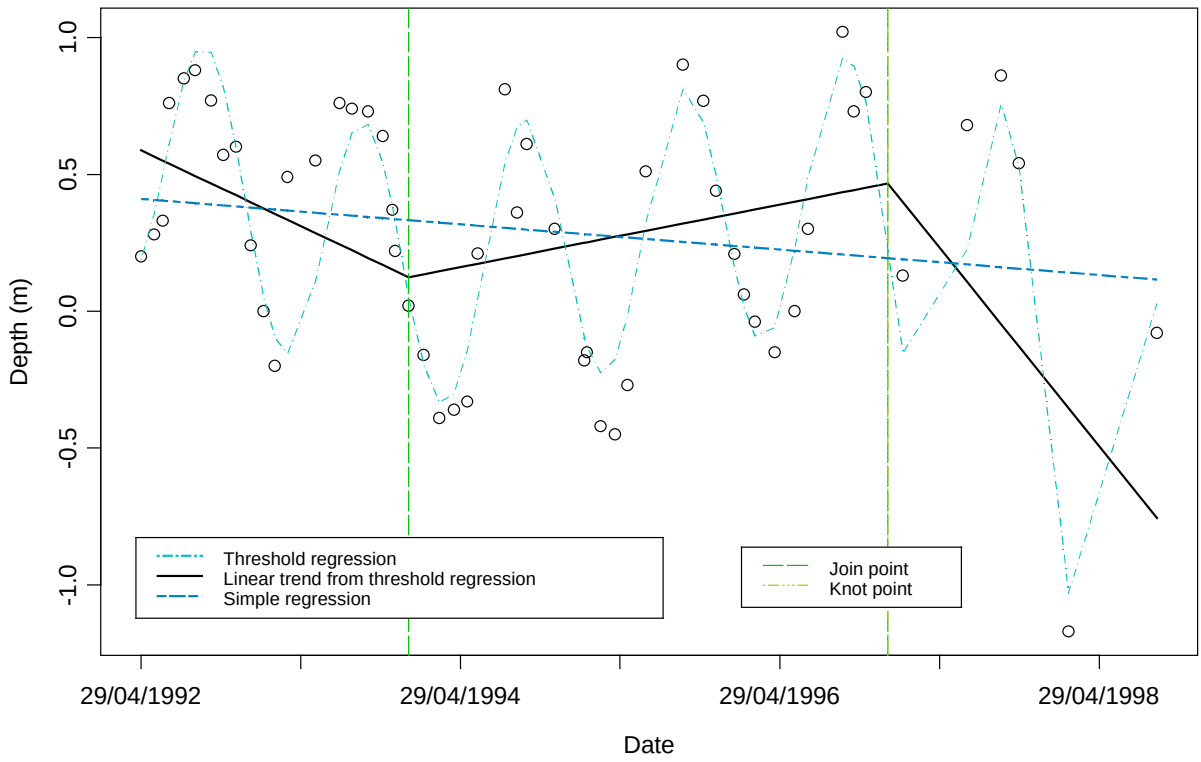


The following model is also fitted:

$$x_t = 8.5283 - 0.2764\,t + 0.3904(t - 34.0247)_+ - 0.8391(t - 37.0247)_+ \\ -0.4913\sin(2\pi t) - 0.3143\delta_{(t-37.0247)}\sin(2\pi t)$$

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/01/1994
2: 01/01/1997
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/01/1997
2:
jy= 34.0246575342466 37.027397260274
ky= 37.027397260274
Please provide  2  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2: 1
3:
```

```
Coefficients:
                  Value Std. Error  t value Pr(>|t|)
    (Intercept)   9.5283   2.0589     4.6279   0.0000
        slope.1  -0.2764   0.0617    -4.4826   0.0000
        slope.2   0.3904   0.0853     4.5776   0.0000
        slope.3  -0.8391   0.1319    -6.3642   0.0000
amplitude.sin.1  -0.4913   0.0399   -12.3176   0.0000
amplitude.sin.2  -0.3143   0.1200    -2.6189   0.0118

Overall Corrected AIC=-2.07285517503943


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  1.9058  1.2931     1.4738  0.1466
sample.year -0.0463  0.0371    -1.2477  0.2177

Corrected AIC for simple linear regression=-0.4704454744525
```



(40) DC50D. There are 68 observations. Dried up frequently.

(41) DC51D. 57 obs. No action. Always –7.75.

(42) DC52I. There are 61 observations. The final model is given by

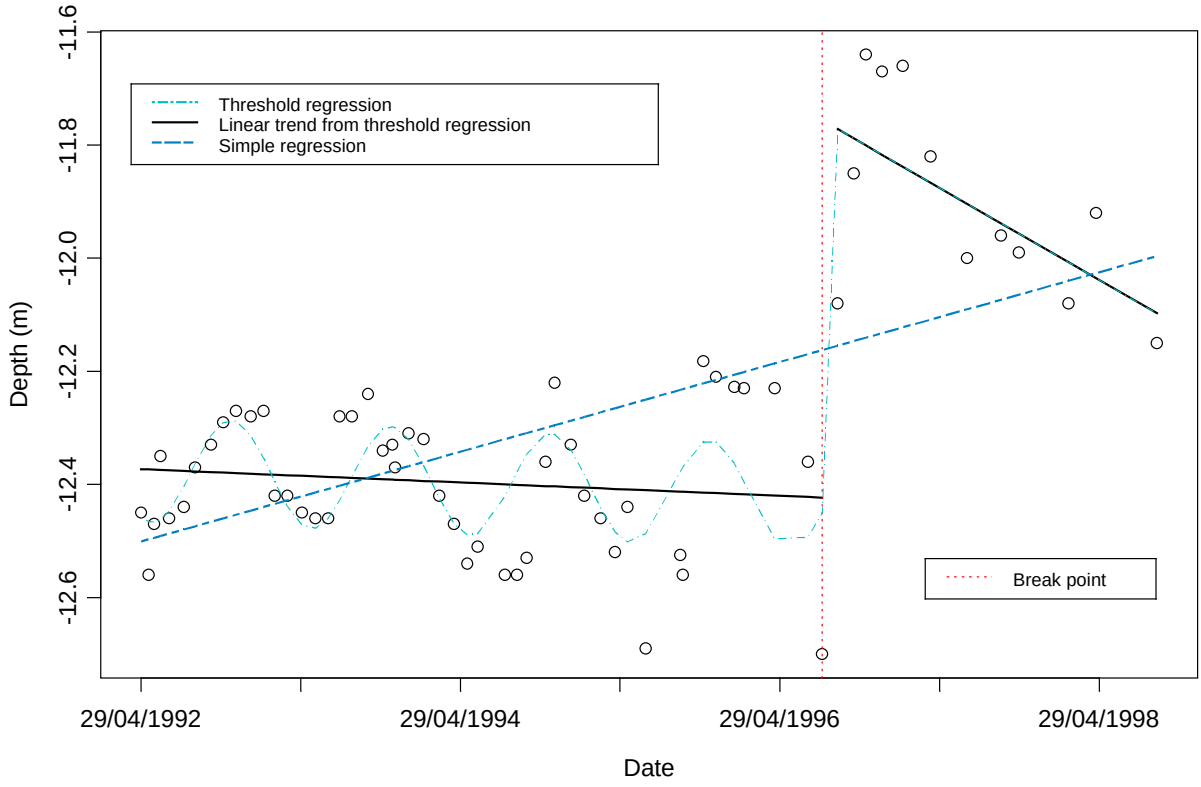
$$x_t = \begin{cases} -11.9924 - 0.0118\,t - 0.0932\sin(2\pi t) & \text{if} \quad t \le 36.4521 \\ -5.8249 - 0.1627\,t & \text{if} \quad t > 36.4521 \end{cases}$$

where the break point was at 04/81996. The estimated linear trend decreased at the rates of 1.18cm/year and 16.27cm/year. The size of jump was 64.38cm. The simple linear regression is

$$x_t = -15.0534 + 0.0793t\,,$$

giving the estimated rate of increase of 7.93cm/year (no trend). The S+ output is below.

```
input break dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A break date is a date at which all the trend changes)
1: 04/08/1996
2:
by= 36.4520547945206

Coefficients:
                  Value Std. Error  t value Pr(>|t|)
    (Intercept) -11.9924   0.4215   -28.4485   0.0000
        slope.1  -0.0118   0.0124    -0.9561   0.3440
amplitude.sin.1  -0.0932   0.0209    -4.4577   0.0001

Coefficients:
             Value Std. Error t value Pr(>|t|)
(Intercept) -5.8249  2.5170    -2.3143  0.0432
    slope.1 -0.1627  0.0674    -2.4146  0.0364

Overall Corrected AIC=-3.19894958981951


Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept) -15.0534   0.5069   -29.6942   0.0000
sample.year   0.0793   0.0146     5.4382   0.0000
Corrected AIC for simple linear regression=-2.15616322820454
```


Threshold regression
Linear trend from threshold regression
Simple regression
Break point
Depth (m)
-11.6
-11.8
-12.0
-12.2
-12.4
-12.6
29/04/1992
29/04/1994
29/04/1996
29/04/1998
Date

(43) DC53I. There are 68 observations. The starting point is at 01/03/1960. The final model is given by

$$x_t = 2.1945 - 0.0927t + 0.3883(t - 35.0219)_+ - 0.4292(t - 37.0247)_+ \\ -0.1624\sin(2\pi t) + 0.1489\delta_{(t-33.0219)}\sin(2\pi t) - 0.1600\delta_{(t-34.0219)}\sin(2\pi t)$$

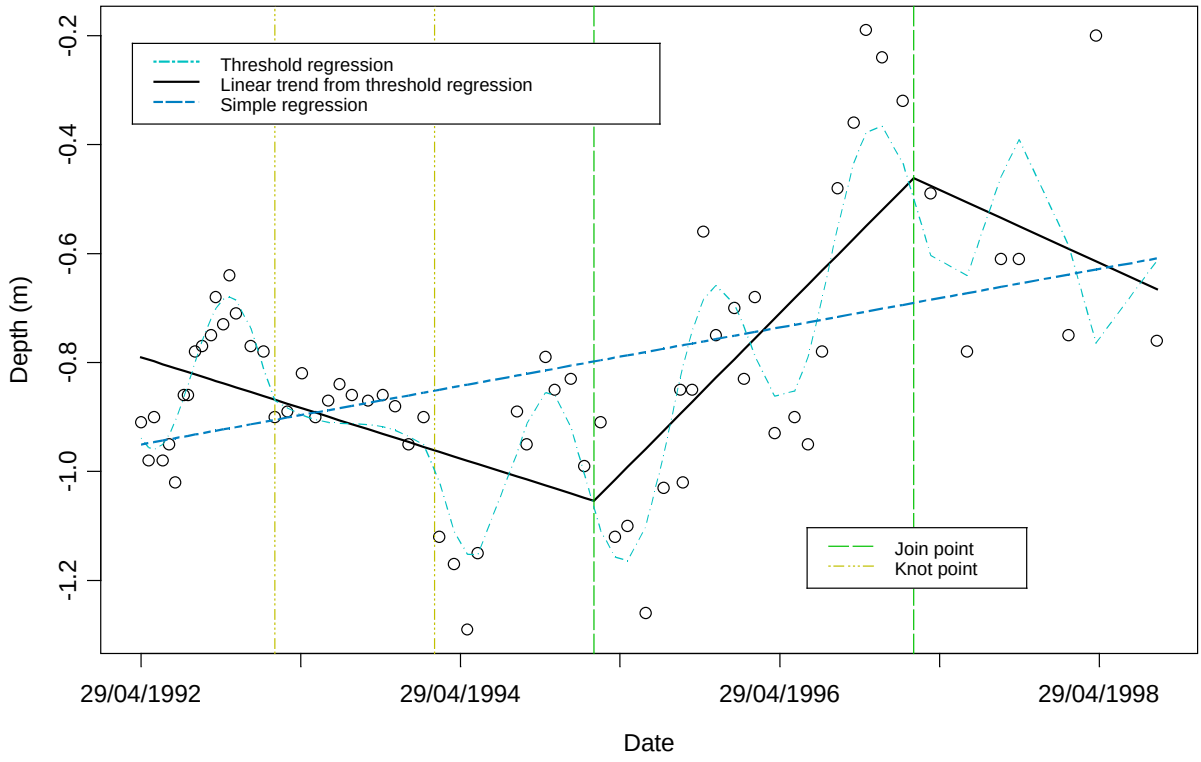
where the join points were at 01/03/1995 and 01/03/1997, the knot points were at 01/03/1993 and 01/03/1994. The estimated linear trend decreased at the rate of 9.27cm/year and the increased at 29.56cm/year, and finally decreased at 13.36cm/year. The simple linear regression is

$$x_t = -2.6671 + 0.0537t,$$

giving the estimated rate of increase of 5.37cm/year (no trend). The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/03/1995
2: 01/03/1997
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/03/1993
2: 01/03/1994
3:
jy= 35.0219178082192 37.0246575342466
ky= 33.0219178082192 34.0219178082192
Please provide  3  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2: 1
3: 1
4:

Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept)  2.1945  0.6194     3.5429  0.0008
        slope.1 -0.0927  0.0184    -5.0275  0.0000
        slope.2  0.3883  0.0450     8.6369  0.0000
        slope.3 -0.4292  0.0878    -4.8899  0.0000
amplitude.sin.1 -0.1624  0.0389    -4.1716  0.0001
amplitude.sin.2  0.1489  0.0624     2.3852  0.0202
amplitude.sin.3 -0.1600  0.0563    -2.8406  0.0061

Overall Corrected AIC=-3.08780637704284
```

```
Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -2.6771  0.4883    -5.4830  0.0000
sample.year  0.0537  0.0141     3.8118  0.0003

Corrected AIC for simple linear regression=-2.09775752012762
```



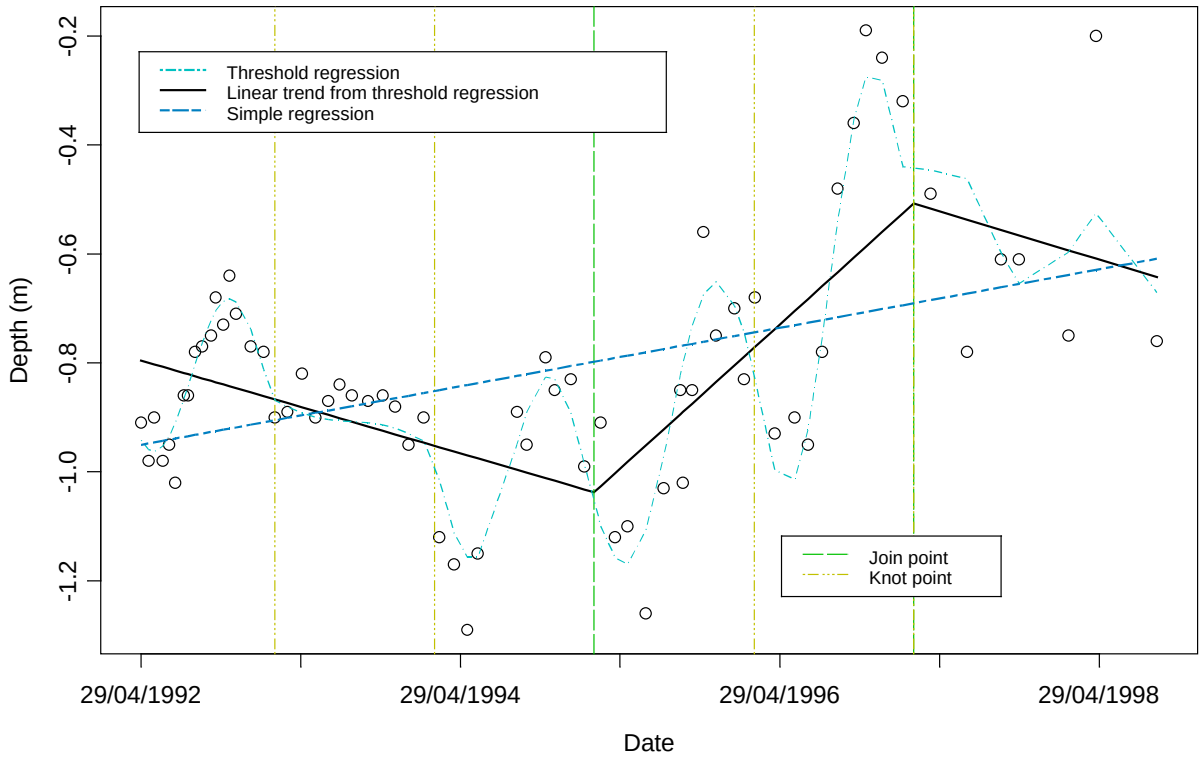
We also fit the following model, which is statistically better than the last one,

$$x_t = 1.9428 - 0.0851t + 0.3495(t - 35.0219)_+ - 0.3529(t - 37.0247)_+ \\ -0.1605\sin(2\pi t) + 0.1493\delta_{(t-33.0219)}\sin(2\pi t) - 0.1776\delta_{(t-34.0219)}\sin(2\pi t) \\ -0.1258\delta_{(t-36.0247)}\sin(2\pi t) + 0.4110\delta_{(t-37.0247)}\sin(2\pi t)$$

The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/03/1995
2: 01/03/1997
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/03/1993
2: 01/03/1994
```

```
3: 01/03/1996
4: 01/03/1997
5:
jy= 35.0219178082192 37.0246575342466
ky=     33.0219178082192     34.0219178082192     36.0246575342466
37.0246575342466

Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept)  1.9428  0.5126     3.7897  0.0004
        slope.1 -0.0851  0.0153    -5.5714  0.0000
        slope.2  0.3495  0.0376     9.2848  0.0000
        slope.3 -0.3529  0.0733    -4.8169  0.0000
amplitude.sin.1 -0.1605  0.0319    -5.0273  0.0000
amplitude.sin.2  0.1493  0.0512     2.9154  0.0050
amplitude.sin.3 -0.1776  0.0498    -3.5668  0.0007
amplitude.sin.4 -0.1258  0.0535    -2.3499  0.0221
amplitude.sin.5  0.4110  0.0735     5.5906  0.0000

Overall Corrected AIC=-3.43812606429177
```



(44) DC54I. There are 68 observations. The starting point is at 01/03/1960. The final model is given by

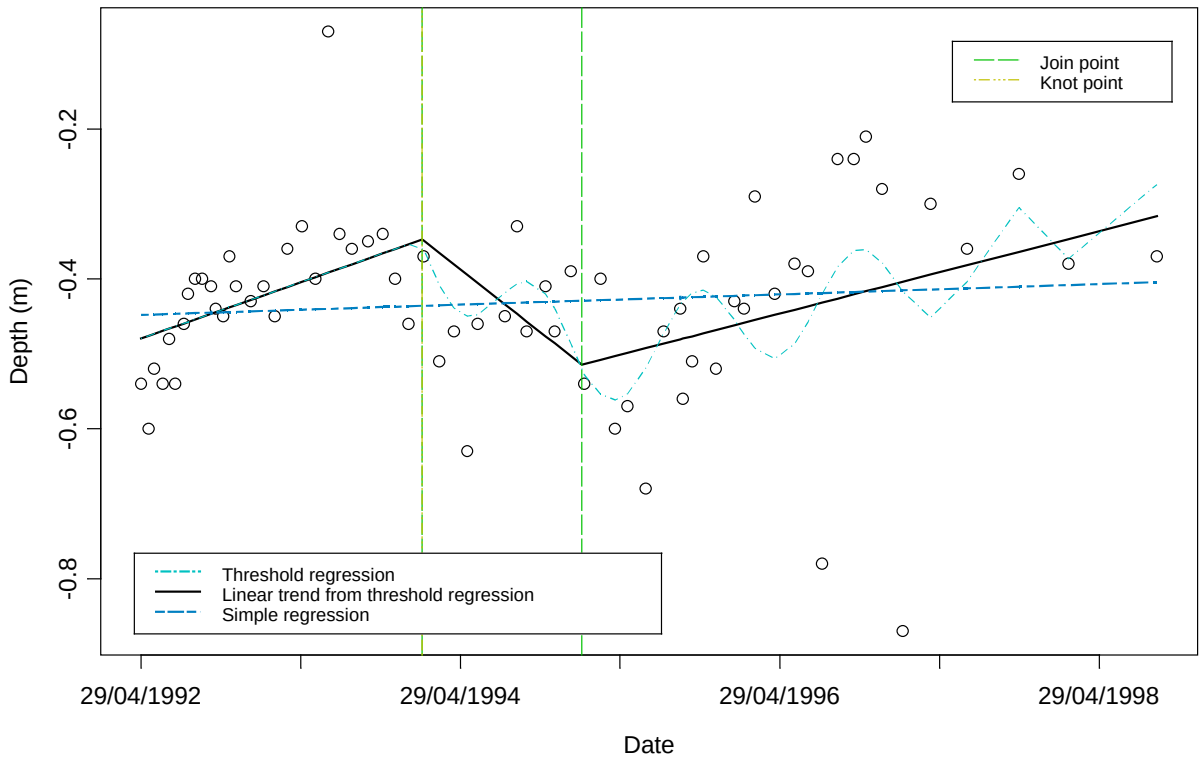
$$x_t = -2.8998 + 0.0750\,t - 0.2421(t - 34.0247)_+ + 0.2221(t - 35.0247)_+ \\ -0.0590\,\delta_{(t-34.0247)}\sin(2\pi t)$$

where the join point was at 01/02/1995, the join and knot point was at 01/02/1994. The estimated linear trend increased at the rate of 7.50cm/year and the decreased at 16.71cm/year, and finally increased at 5.50cm/year. The simple linear regression is

$$x_t = -0.6689 + 0.0068t,$$

giving the estimated rate of increase of 0.68cm/year (no trend). The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/02/1994
2: 01/02/1995
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/02/1994
2:
jy= 34.0246575342466 35.0246575342466
ky= 34.0246575342466
Please provide  2  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 0
2: 1
3:

Coefficients:
                 Value Std. Error t value Pr(>|t|)
    (Intercept) -2.8998  1.1810    -2.4554  0.0169
        slope.1  0.0750  0.0357     2.1020  0.0396
        slope.2 -0.2421  0.0845    -2.8653  0.0057
        slope.3  0.2221  0.0706     3.1452  0.0025
amplitude.sin.2 -0.0590  0.0263    -2.2421  0.0285

Overall Corrected AIC=-3.18621296550384


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -0.6689  0.3156    -2.1192  0.0379
sample.year  0.0068  0.0091     0.7515  0.4550

Corrected AIC for simple linear regression=-3.07599041371508
```


Join point
Knot point
Threshold regression
Linear trend from threshold regression
Simple regression
Depth (m)
-0.2
-0.4
-0.6
-0.8
29/04/1992
29/04/1994
29/04/1996
29/04/1998
Date

(45) DC55I. There are 61 observations. The final model is given by

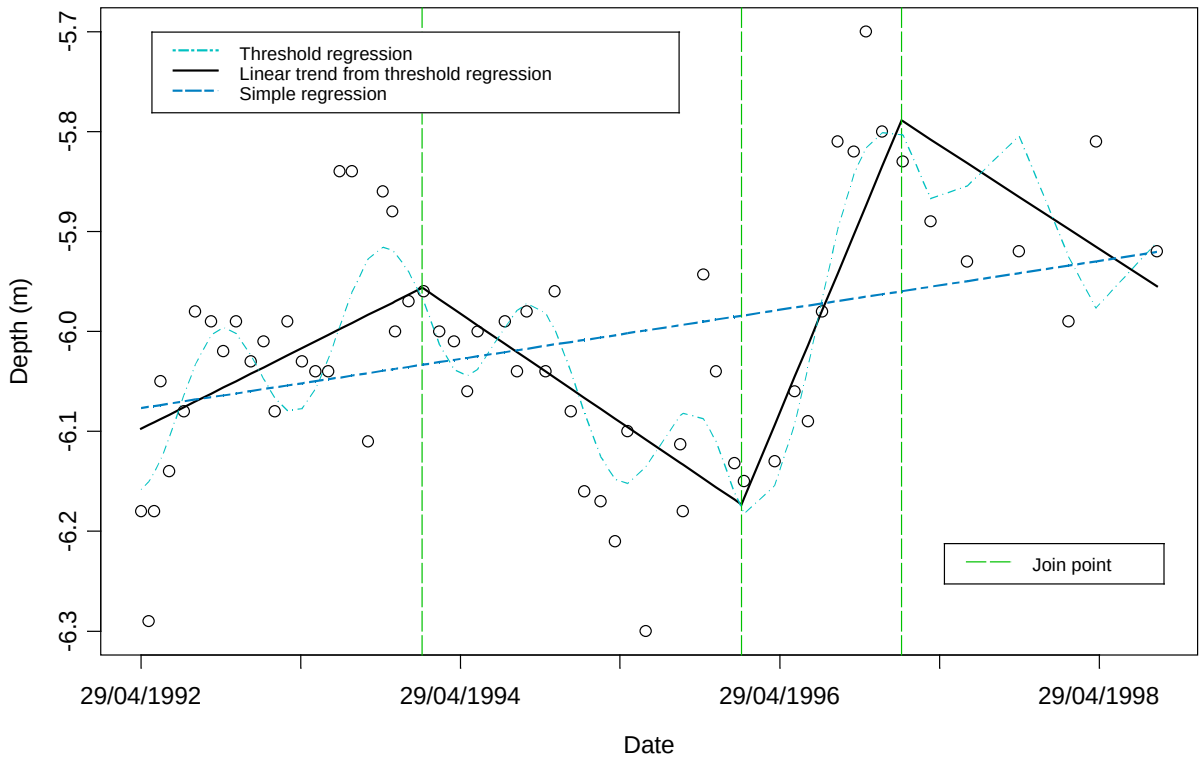
$$x_t = -8.6823 + 0.0801t - 0.1885(t - 34.0247)_+ + 0.4869(t - 36.0247)_+ - 0.4869(t - 37.0247)_+ \\ -0.0621\sin(2\pi t)$$

where the join points were at 01/02/1994, 01/02/1996 and 01/02/1997. The estimated linear trend increased at the rate of 8.01cm/year and then decreased at 10.04cm/year, and increased again at 39.11cm/year, and finally decreased at 9.58cm/year. The simple linear regression is

$$x_t = -6.8679 + 0.0245t,$$

giving the estimated rate of increase of 2.45cm/year. The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/02/1994
2: 01/02/1996
3: 01/02/1997
4:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1:
jy= 34.0246575342466 36.0246575342466 37.027397260274
Please provide  1  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2:

Coefficients:
                  Value Std. Error  t value Pr(>|t|)
    (Intercept)  -8.6823   0.7326   -11.8518   0.0000
        slope.1   0.0801   0.0220     3.6393   0.0006
        slope.2  -0.1885   0.0368    -5.1249   0.0000
        slope.3   0.4915   0.0605     8.1266   0.0000
        slope.4  -0.4869   0.0795    -6.1251   0.0000
amplitude.sin.1  -0.0612   0.0131    -4.6616   0.0000

Overall Corrected AIC=-4.04931775517502


Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept)  -6.8679   0.3034   -22.6351   0.0000
sample.year   0.0245   0.0087     2.8142   0.0066

Corrected AIC for simple linear regression=-3.21781615915078
```


Threshold regression
Linear trend from threshold regression
Simple regression
Join point
Depth (m)
-5.7
-5.8
-5.9
-6.0
-6.1
-6.2
-6.3
29/04/1992
29/04/1994
29/04/1996
29/04/1998
Date

(46) DC56I. There are 69 observations. The final model is given by

$$x_t = -3.6425 + 0.1577\,t - 0.3647(t - 34.0247)_+ + 0.2952(t - 35.0247)_+ - 0.1010(t - 37.0247)_+ \\ -0.1049\delta_{(t-36.0247)}\sin(2\pi t) + 0.1366\delta_{(t-37.0247)}\sin(2\pi t)$$

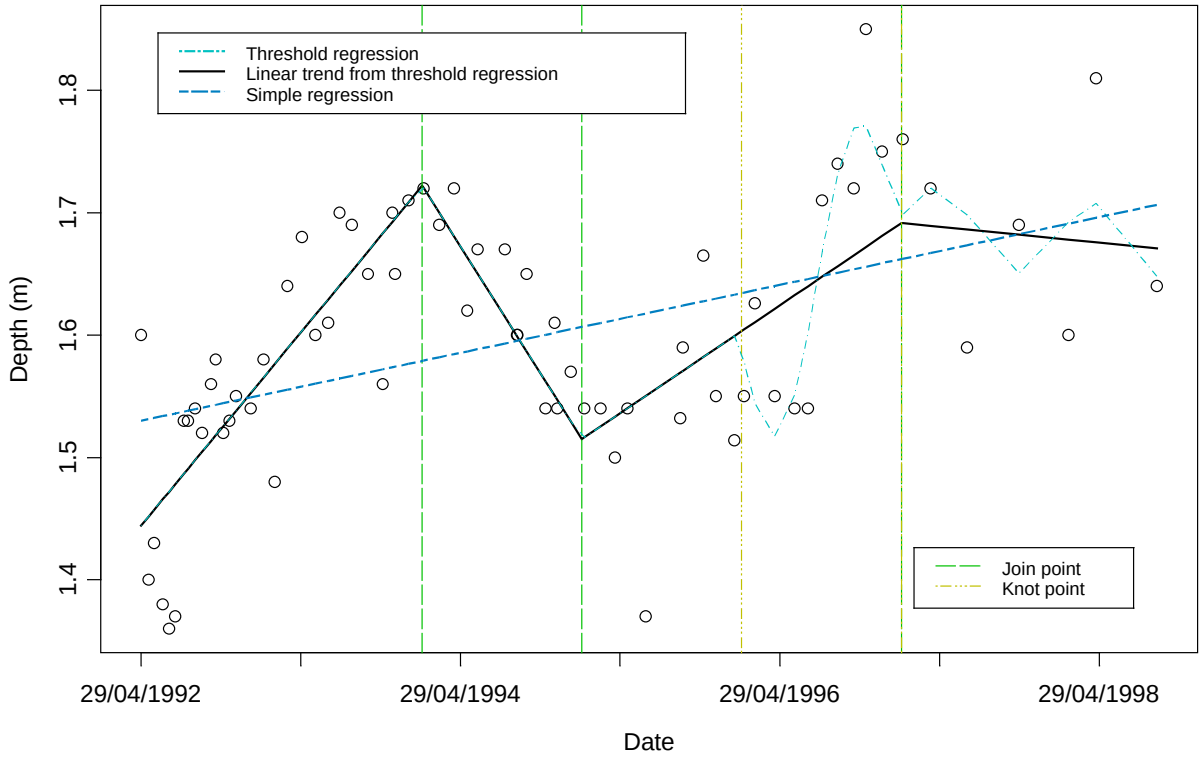
where the join points were at 01/02/1994, 01/02/1995, the knot point was at 01/02/1996, and the join and knot point was at 01/02/1997. The estimated linear trend increased at the rate of 15.77cm/year and then decreased at 20.70cm/year, and increased again at 8.82cm/year, and finally decreased at 1.28cm/year. The simple linear regression is

$$x_t = -0.6358 + 0.0277t,$$

giving the estimated rate of increase of 2.77cm/year. The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/02/1994
2: 01/02/1995
3: 01/02/1997
4:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/02/1996
2: 01/02/1997
3:
jy= 34.0246575342466 35.0246575342466 37.027397260274
ky= 36.0246575342466 37.027397260274
Please provide  3  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 0
2: 1
3: 1
4:
Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept) -3.6425  0.6155    -5.9180  0.0000
        slope.1  0.1577  0.0186     8.4839  0.0000
        slope.2 -0.3647  0.0459    -7.9377  0.0000
        slope.3  0.2952  0.0453     6.5107  0.0000
        slope.4 -0.1010  0.0455    -2.2201  0.0301
amplitude.sin.2 -0.1049  0.0289    -3.6290  0.0006
amplitude.sin.3  0.1366  0.0446     3.0644  0.0032

Overall Corrected AIC=-4.39377641900054


Coefficients:
             Value Std. Error t value Pr(>|t|)
(Intercept) 0.6358 0.2256     2.8176  0.0064
```

```
sample.year 0.0277 0.0065     4.2600  0.0001

Corrected AIC for simple linear regression=-3.69018589902272
```



(47) DC60I. DC56I. There are 68 observations. The final model is given by

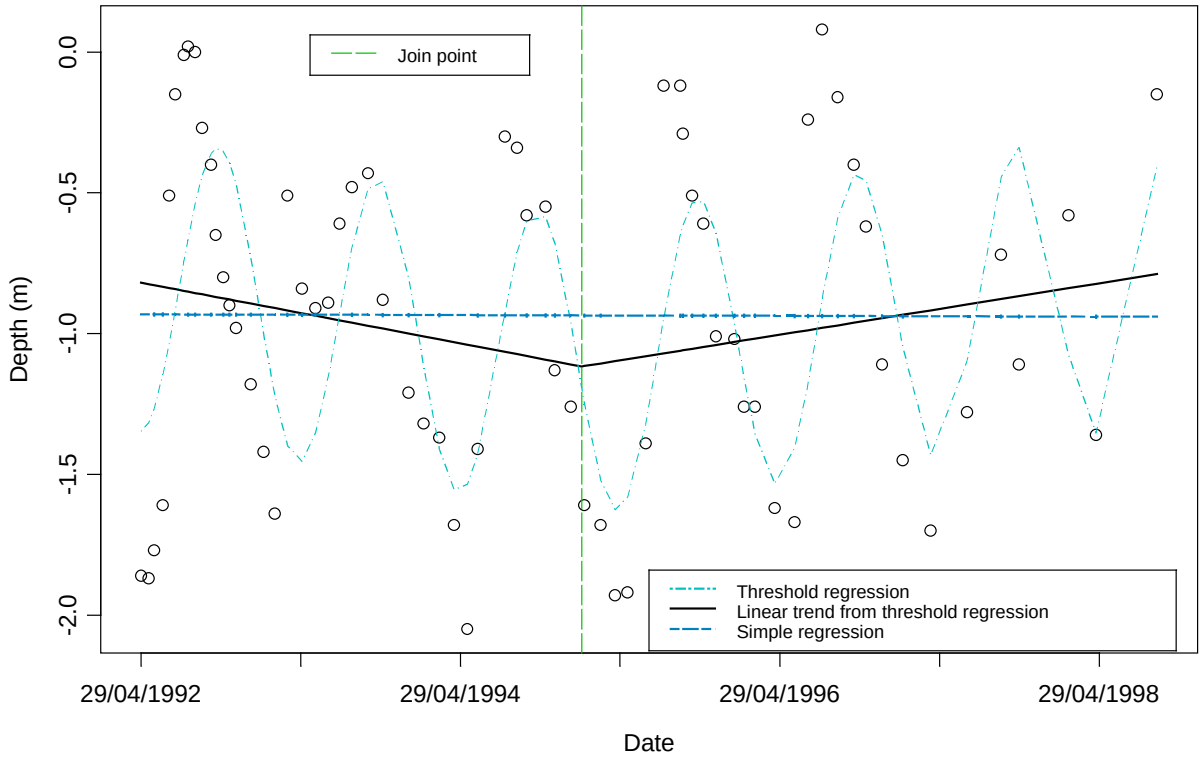
$$x_t = 2.6615 - 0.1079t + 0.1991(t - 35.0247)_+ - 0.5305\sin(2\pi t)$$

where the join point was at 01/02/1995. The estimated linear trend decreased at the rate of 10.79cm/year and then increased at 9.12cm/year. The simple linear regression is

$$x_t = -0.8869 - 0.0014t,$$

giving the estimated rate of increase of 0.14cm/year. The S+ output is below.

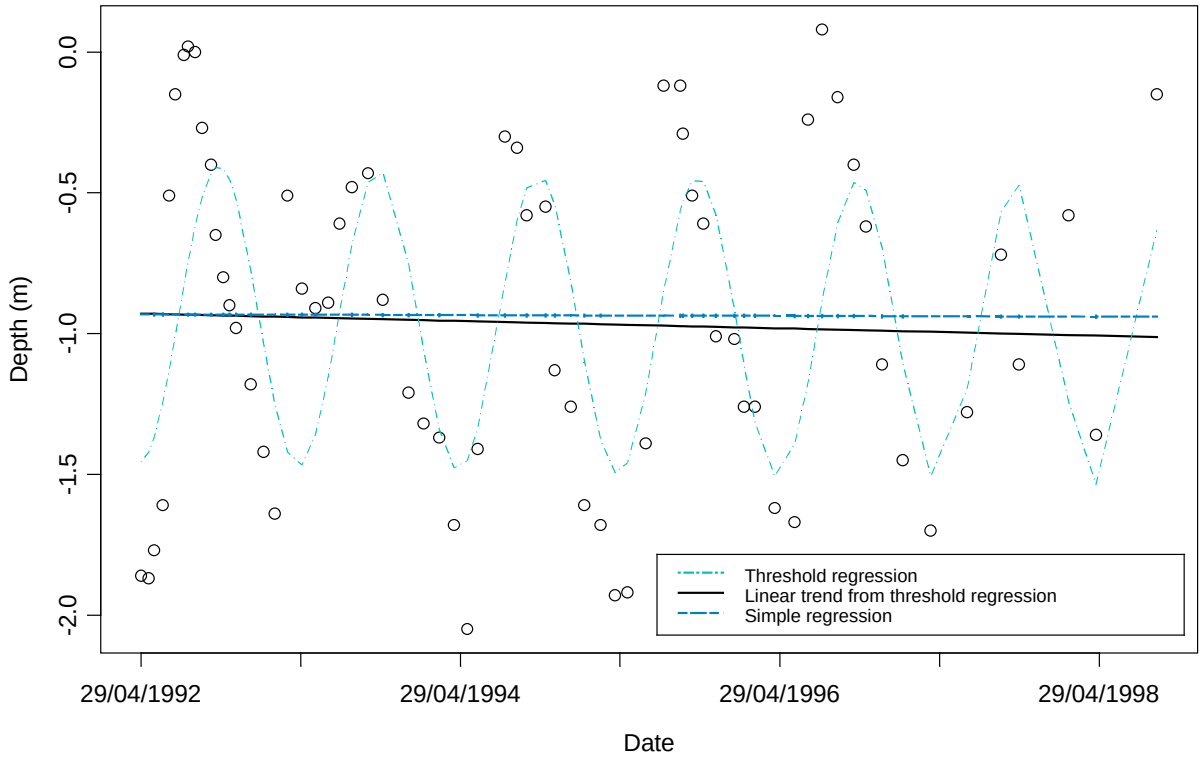
```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/02/1995
2:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1:
jy= 35.0246575342466
Please provide  1  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2:

Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept)  2.6615  2.2117     1.2033  0.2333
        slope.1 -0.1079  0.0656    -1.6451  0.1049
        slope.2  0.1991  0.1214     1.6399  0.1059
amplitude.sin.1 -0.5305  0.0752    -7.0534  0.0000

Overall Corrected AIC=-0.507835386571596


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -0.8869  1.4251    -0.6224  0.5358
sample.year -0.0014  0.0410    -0.0337  0.9732

Corrected AIC for simple linear regression=0.0358311748906961
```



For a comparison, we also fit the following model:

$$x_t = -0.5080 - 0.0130\,t - 0.5292\sin(2\pi t)$$

```
Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept) -0.5080  1.0892    -0.4664  0.6425
        slope.1 -0.0130  0.0313    -0.4165  0.6784
amplitude.sin.1 -0.5292  0.0762    -6.9464  0.0000

Overall Corrected AIC=-0.500978399071858
```


Depth (m)
0.0
-0.5
-1.0
-1.5
-2.0
29/04/1992
29/04/1994
29/04/1996
29/04/1998
Date
Threshold regression
Linear trend from threshold regression
Simple regression

(48) DC61AQ. There are 65 observations. The final model is given by

$$x_t = 9.3292 - 0.2520t + 0.3904(t - 34.0247)_+ - 0.2277(t - 37.0274)_+ \\ -0.2703\sin(2\pi t) - 0.2124\delta_{(t-34.0247)}\sin(2\pi t) + 0.1708\delta_{(t-37.0247)}\sin(2\pi t)$$

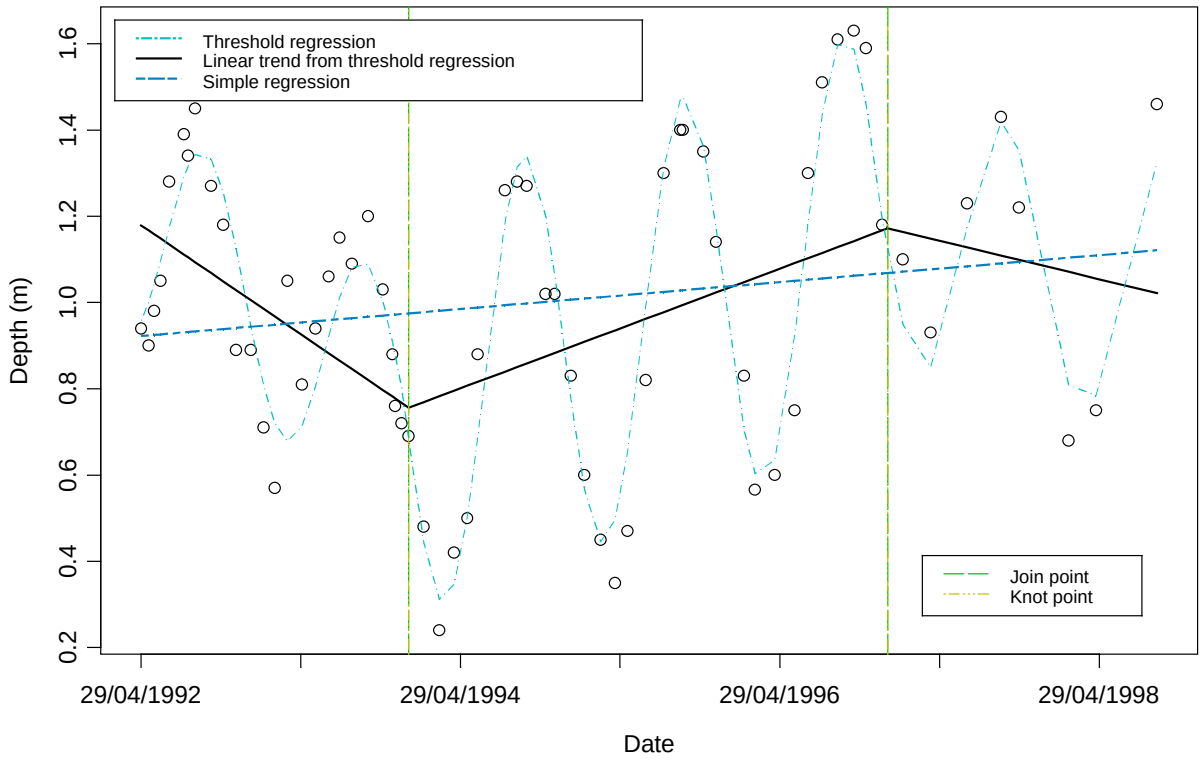
where the join and knot points were at 01/01/1994 and 01/01/1997. The estimated linear trend decreased at the rate of 25.20cm/year and then increased at 13.84cm/year and finally decreased at 8.93cm/year. The simple linear regression is

$$x_t = -0.0876 - 0.0312t,$$

giving the estimated rate of increase of 3.12cm/year (no significant trend). The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/01/1994
2: 01/01/1997
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/01/1994
2: 01/01/1997
3:
jy= 34.0246575342466 37.027397260274
ky= 34.0246575342466 37.027397260274
Please provide  3  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2: 1
3: 1
4:

Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept)  9.3292  1.0941     8.5269  0.0000
        slope.1 -0.2520  0.0328    -7.6821  0.0000
        slope.2  0.3904  0.0458     8.5252  0.0000
        slope.3 -0.2277  0.0644    -3.5355  0.0008
amplitude.sin.1 -0.2703  0.0352    -7.6882  0.0000
amplitude.sin.2 -0.2124  0.0460    -4.6165  0.0000
amplitude.sin.3  0.1708  0.0579     2.9503  0.0046

Overall Corrected AIC=-3.17037732717395


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -0.0876  0.8511    -0.1029  0.9184
sample.year  0.0312  0.0244     1.2805  0.2051
```

Corrected AIC for simple linear regression=-1.08580638032947



(49) DC61I. There are 69 observations. The first 18 observations are removed because the bore was dried up (-11m). Only 51 observations are used in analysis. The final model is given by

$$x_t = 4.1539 - 0.3399\,t + 3.8499(t - 36.0247)_+ - 2.8006(t - 37.0274)_+ \\ -1.1078\sin(2\pi t) - 0.7231\delta_{(t-35.0247)}\sin(2\pi t) + 1.1152\delta_{(t-36.0247)}\sin(2\pi t)$$

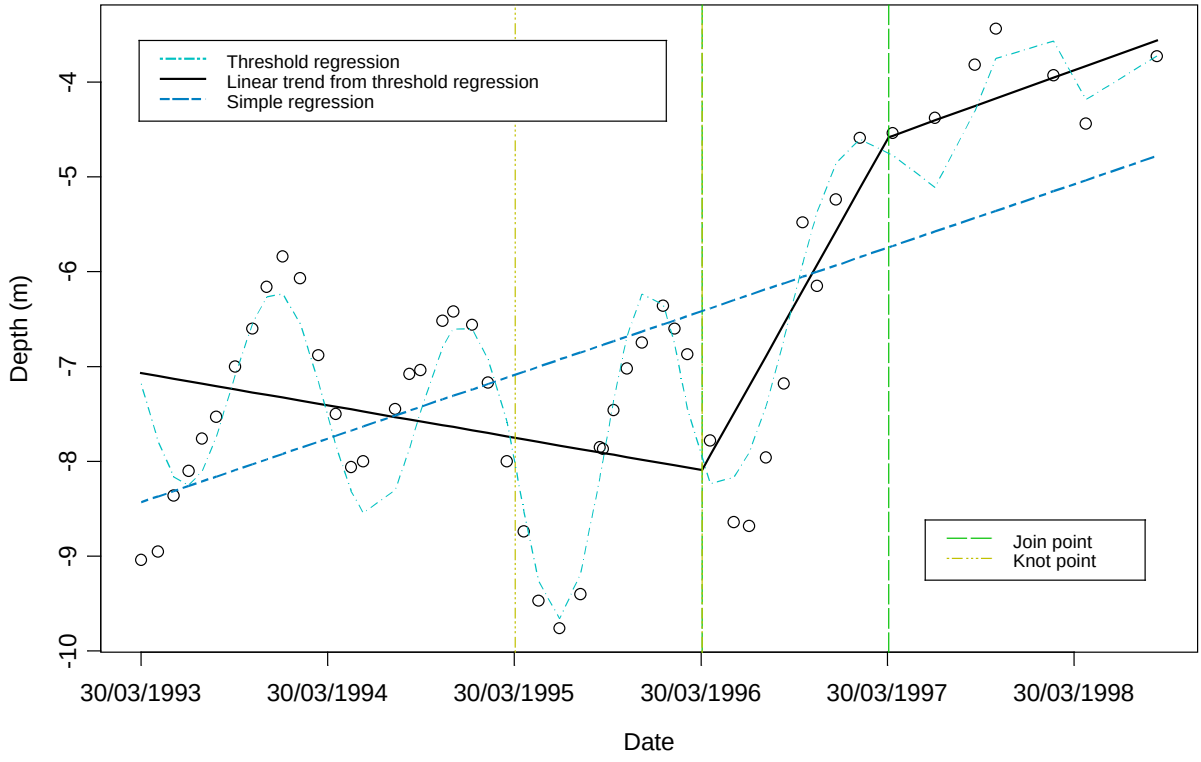
where the join point was at 01/04/1997, the knot point was at 01/04/1995. the join and knot point was at 01/04/1996. The estimated linear trend decreased at the rate of 33.99cm/year and then increased at 351.00cm/year and 70.94cm/year. The simple linear regression is

$$x_t = -30.5463 + 0.6698t\,,$$

giving the estimated rate of increase of 3.12cm/year (no significant trend). The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/04/1996
2: 01/04/1997
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/04/1995
2: 01/04/1996
3:
jy= 36.0246575342466 37.0246575342466
ky= 35.0219178082192 36.0246575342466
Please provide  3  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2: 1
3: 1
4:

Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept)  4.1539  3.3485     1.2405  0.2214
        slope.1 -0.3399  0.0968    -3.5125  0.0010
        slope.2  3.8499  0.4052     9.5014  0.0000
        slope.3 -2.8006  0.6452    -4.3409  0.0001
amplitude.sin.1 -1.1078  0.1628    -6.8039  0.0000
amplitude.sin.2 -0.7231  0.2816    -2.5678  0.0137
amplitude.sin.3  1.1152  0.3222     3.4607  0.0012


Overall Corrected AIC=-0.0287610179832973


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

```
(Intercept) -30.5463   4.3774    -6.9783   0.0000
sample.year   0.6698   0.1239     5.4050   0.0000

Corrected AIC for simple linear regression=1.57737542615833
```



(50) DC62I. There are 62 observations. The starting point is choose as 01/01/1960. The final model is given by

$$x_t = 4.0082 - 0.1158t + 0.3898(t - 35.0247)_+ - 0.4365(t - 37.0274)_+ \\ -0.2794\sin(2\pi t) - 0.2245\delta_{(t-34.0247)}\sin(2\pi t) + 0.1717\delta_{(t-37.0247)}\sin(2\pi t)$$

where the join point was at 01/01/1995, the knot point was at 01/01/1994. the join and knot point was at 01/01/1997. The estimated linear trend decreased at the rate of 11.85cm/year and then increased at 27.40cm/year and finally increased at 16.25cm/year. The simple linear regression is

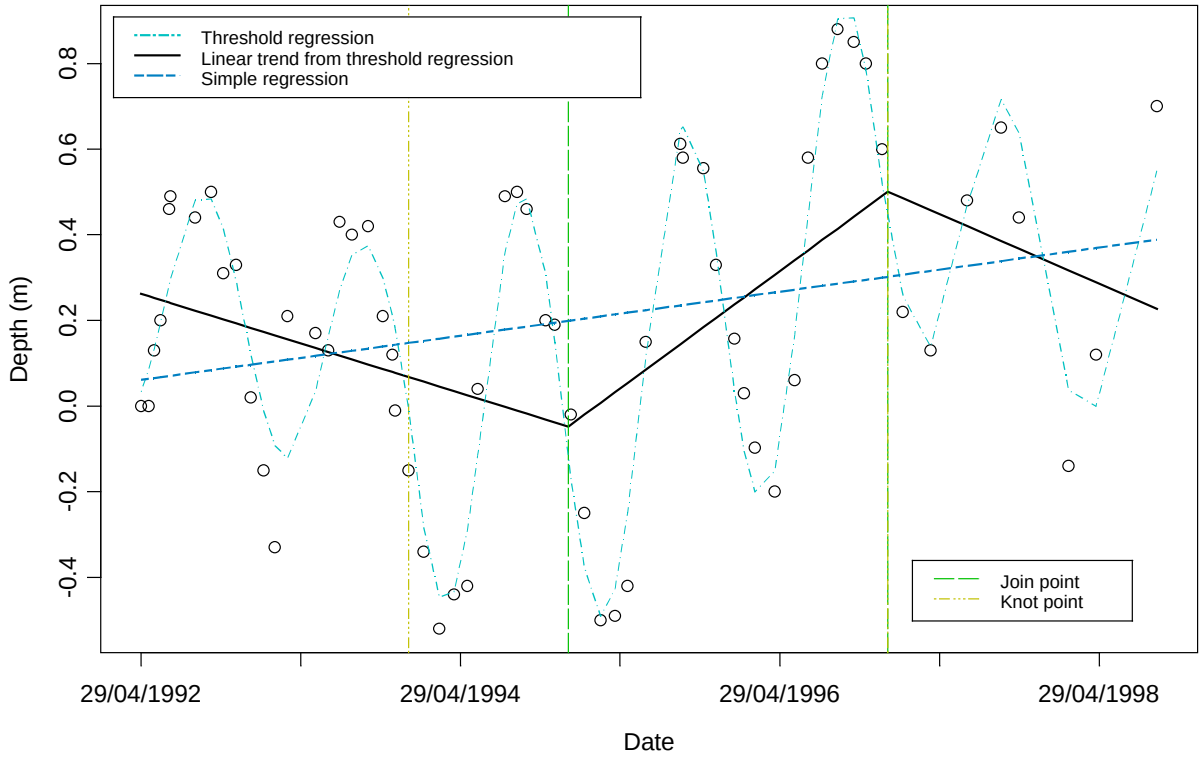
$$x_t = -1.6034 + 0.0515t,$$

giving the estimated rate of increase of 5.15cm/year. The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/01/1995
2: 01/01/1997
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/01/1994
2: 01/01/1997
3:
jy= 35.0246575342466 37.027397260274
ky= 34.0246575342466 37.027397260274
Please provide  3  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2: 1
3: 1
4:

Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept)  4.0082  0.7146     5.6094  0.0000
        slope.1 -0.1158  0.0212    -5.4754  0.0000
        slope.2  0.3898  0.0462     8.4413  0.0000
        slope.3 -0.4365  0.0790    -5.5249  0.0000
amplitude.sin.1 -0.2794  0.0394    -7.0868  0.0000
amplitude.sin.2 -0.2245  0.0499    -4.4956  0.0000
amplitude.sin.3  0.1717  0.0604     2.8413  0.0063

Overall Corrected AIC=-3.0774741981775


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -1.6034  0.9112    -1.7597  0.0836
```

```
sample.year  0.0515  0.0260     1.9762  0.0527
```

```
Corrected AIC for simple linear regression=-0.9880685984128
```



(51) DC80AQ. No analysis can be done because nearly all data have value of 1.4.

(52) DC81AQ. There are 65 observations. The first observation at 29-Apr-92 having the value of 1.1 was removed from the analysis as it seems to be an outlier. The starting point is choose as 01/01/1960. The final model is given by

$$x_t = 4.3180 - 0.0853t + 0.1344(t - 35.0247)_+ \\ -0.0657\sin(2\pi t) - 0.0830\delta_{(t-34.0247)}\sin(2\pi t) + 0.1108\delta_{(t-35.0247)}\sin(2\pi t)$$

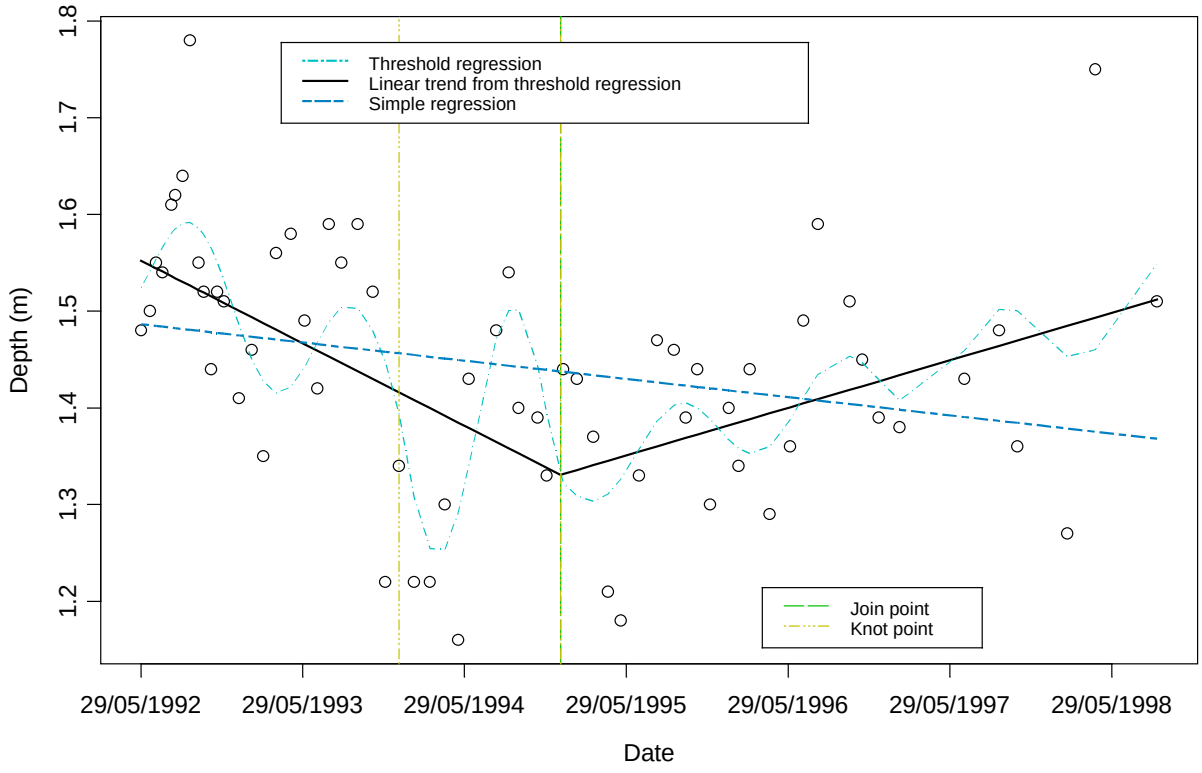
where the knot point was at 01/01/1994. the join and knot point was at 01/01/1995. The estimated linear trend decreased at the rate of 8.53cm/year and then increased at 4.91cm/year. The simple linear regression is

$$x_t = 2.0962 - 0.0188t\,,$$

giving the estimated rate of increase of 1.88cm/year. The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/01/1995
2:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/01/1994
2: 01/01/1995
3:
jy= 35.0246575342466
ky= 34.0246575342466 35.0246575342466
Please provide  3  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2: 1
3: 1
4:

Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept)  4.3180  0.5499     7.8525  0.0000
        slope.1 -0.0853  0.0162    -5.2561  0.0000
        slope.2  0.1344  0.0280     4.7960  0.0000
amplitude.sin.1 -0.0657  0.0301    -2.1852  0.0329
amplitude.sin.2 -0.0830  0.0511    -1.6258  0.1094
amplitude.sin.3  0.1108  0.0481     2.3051  0.0248

Overall Corrected AIC=-3.53328129522872


Coefficients:
```

```
                Value Std. Error t value Pr(>|t|)
(Intercept)  2.0962  0.3184     6.5844  0.0000
sample.year -0.0188  0.0091    -2.0584  0.0438
Corrected AIC for simple linear regression=-3.0697173965161
```



(53) DC91M. There are 40 observations. The final model is given by

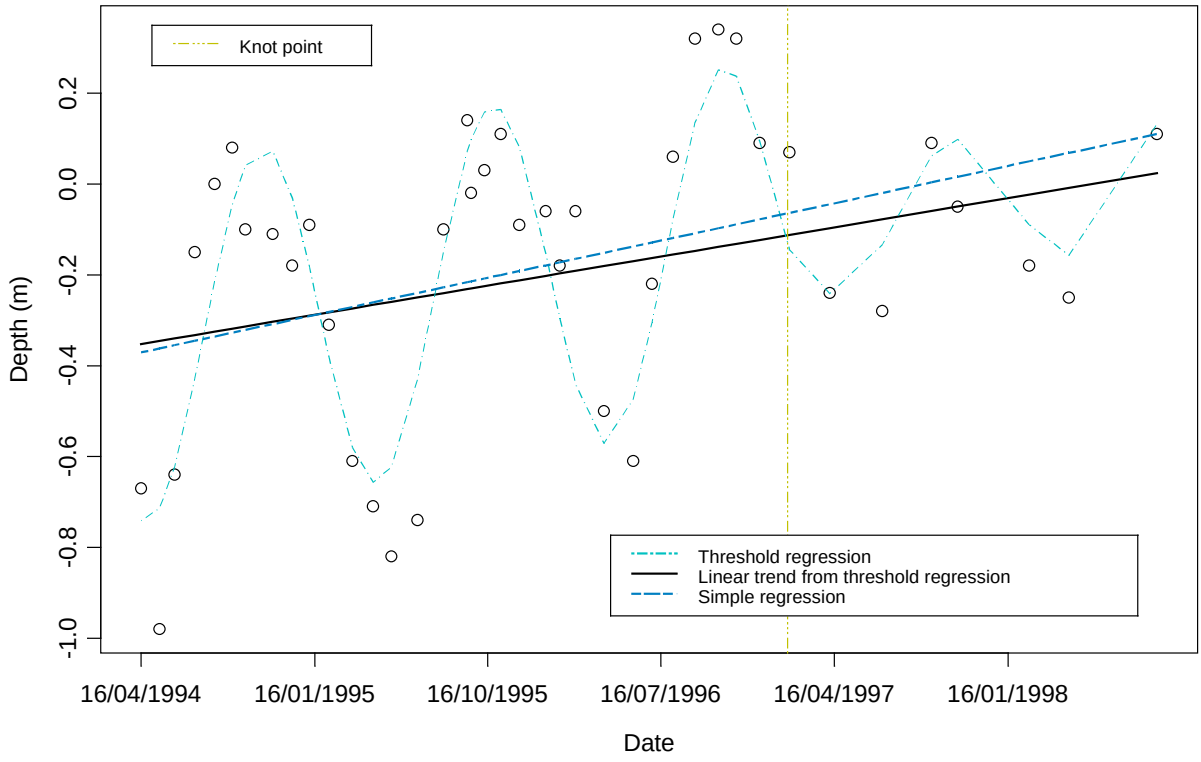
$$x_t = -3.2821 + 0.0856t - 0.3929\sin(2\pi t) + 0.2442\delta_{(t-37.0247)}\sin(2\pi t)$$

where the knot point was at 01/02/1997. The estimated linear trend increased at the rate of 8.56cm/year. The simple linear regression is

$$x_t = -4.1111 + 0.1093t,$$

giving the estimated rate of increase of 10.93cm/year. The S+ output is below.

```
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/02/1997
2:
ky= 37.027397260274
Please provide  2  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2: 1
3:

Coefficients:
                 Value Std. Error  t value Pr(>|t|)
    (Intercept)  -3.2821   0.7745    -4.2376   0.0001
        slope.1   0.0856   0.0215     3.9767   0.0003
amplitude.sin.1  -0.3929   0.0389   -10.1093   0.0000
amplitude.sin.2   0.2442   0.0838     2.9141   0.0061

Overall Corrected AIC=-2.51219579910895


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -4.1111  1.4906    -2.7580  0.0089
sample.year  0.1093  0.0414     2.6388  0.0120
```


Knot point
Threshold regression
Linear trend from threshold regression
Simple regression
Depth (m)
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
16/04/1994
16/01/1995
16/10/1995
16/07/1996
16/04/1997
16/01/1998
Date

(54) DC92M. There are 40 observations. The final model is given by

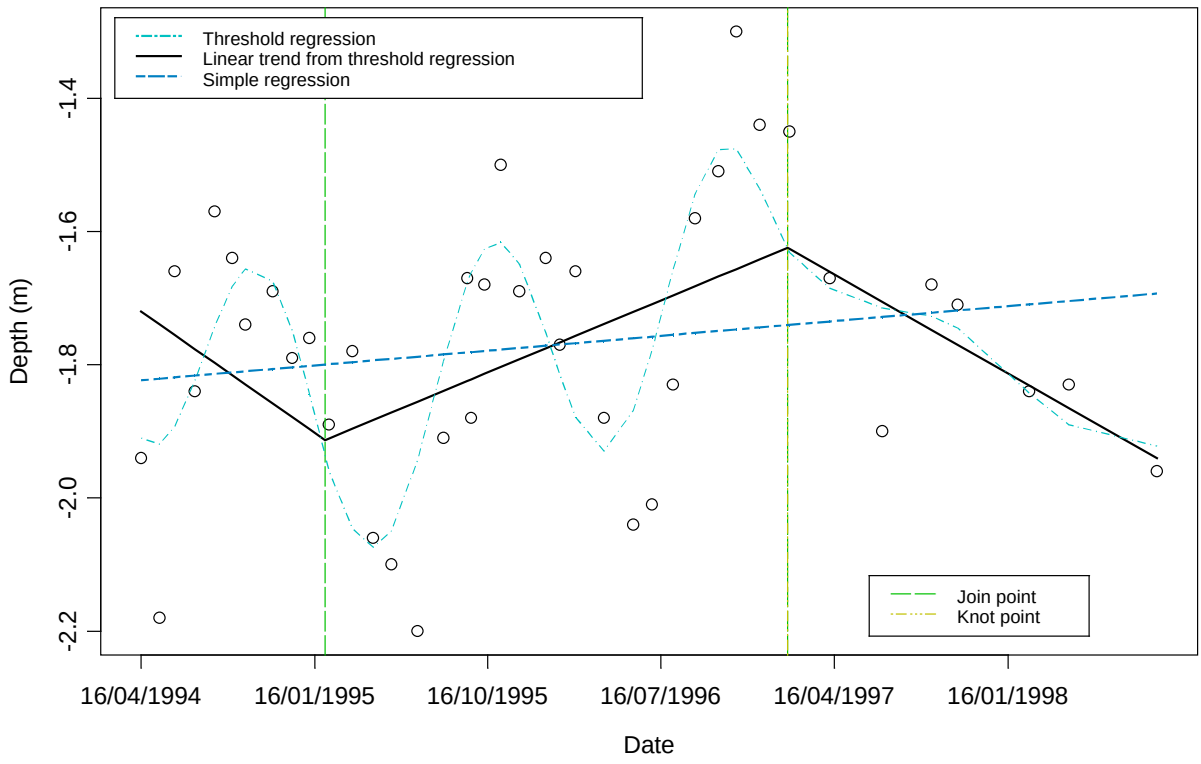
$$x_t = 6.5665 - 0.2421t + 0.3863(t - 35.0247)_+ - 0.3417(t - 37.0247)_+ \\ -0.1919\sin(2\pi t) + 0.1668\delta_{(t-35.0247)}\sin(2\pi t)$$

where the join point was at 01/02/1995. The join and knot point was at 01/02/1997. The estimated linear trend decreased at the rate of 24.21cm/year and then increased at 14.42cm/year and finally decreased at 19.75cm/year. The simple linear regression is

$$x_t = -2.8370 + 0.0296\,t,$$

giving the estimated rate of increase of 2.96cm/year (no trend). The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/02/1995
2: 01/02/1997
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/02/1997
2:
jy= 35.0246575342466 37.027397260274
ky= 37.027397260274
Please provide  2  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2: 1
3:

Coefficients:
                 Value Std. Error t value Pr(>|t|)
    (Intercept)  6.5665  4.4191     1.4859  0.1465
        slope.1 -0.2421  0.1271    -1.9043  0.0654
        slope.2  0.3863  0.1546     2.4981  0.0175
        slope.3 -0.3417  0.1050    -3.2530  0.0026
amplitude.sin.1 -0.1919  0.0361    -5.3154  0.0000
amplitude.sin.2  0.1668  0.0777     2.1479  0.0389

Overall Corrected AIC=-2.62158087489584


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -2.8370  0.9886    -2.8698  0.0067
sample.year  0.0296  0.0275     1.0782  0.2878
Corrected AIC for simple linear regression=-2.06054286665819
```


Threshold regression
Linear trend from threshold regression
Simple regression
Join point
Knot point
Depth (m)
-1.4
-1.6
-1.8
-2.0
-2.2
16/04/1994
16/01/1995
16/10/1995
16/07/1996
16/04/1997
16/01/1998
Date

(55) DC93I. There are 40 observations. The final model is given by

$$x_t = -0.7009 - 0.1812\,t + 0.5363(t - 35.0247)_+ - 0.5138(t - 37.0247)_+ \\ -0.2894\sin(2\pi t) + 0.2223\delta_{(t-35.0247)}\sin(2\pi t) - 0.2413\delta_{(t-36.0247)}\sin(2\pi t) + 0.3791\delta_{(t-37.0247)}\sin(2\pi t)$$

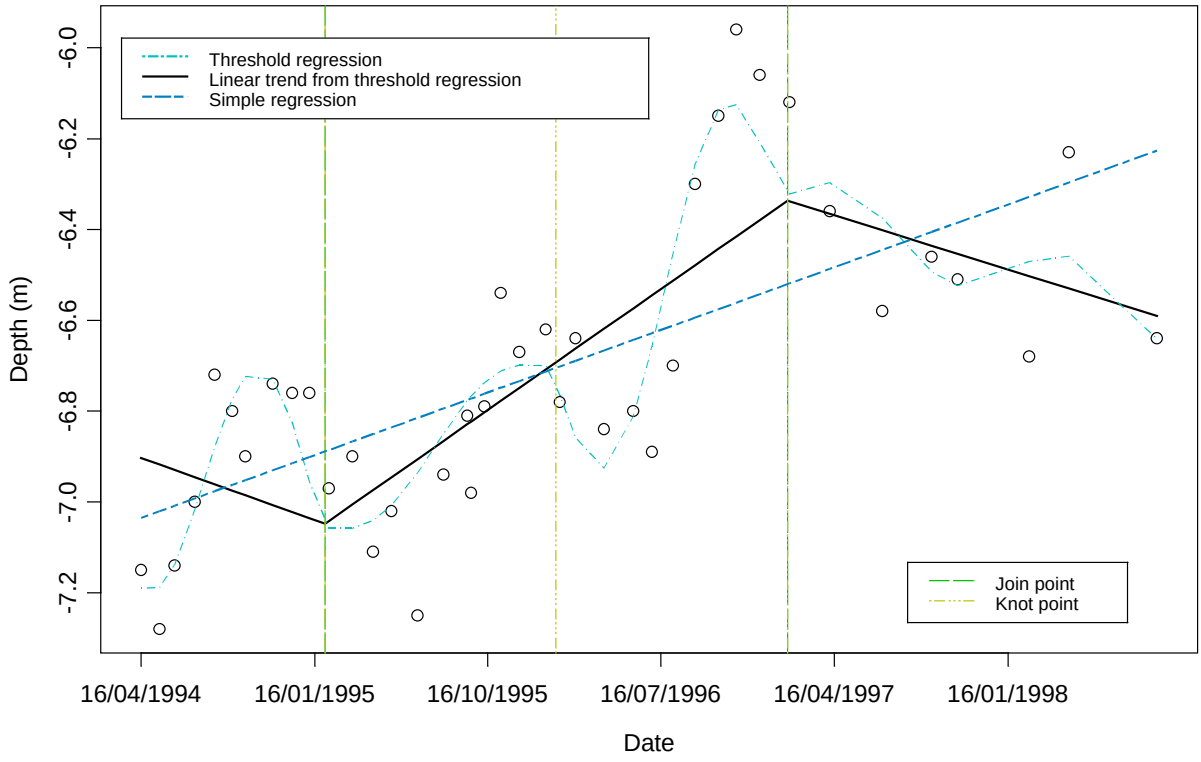
where the knot point was at 01/02/1996. The join and knot points were at 01/02/1995 and 01/02/1997. The estimated linear trend decreased at the rate of 18.12cm/year and then increased at 35.51cm/year and finally decreased at 15.87cm/year. The simple linear regression is

$$x_t = -13.3243 + 0.1838\,t,$$

giving the estimated rate of increase of 18.38cm/year (no trend). The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/02/1995
2: 01/02/1997
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/02/1995
2: 01/02/1996
3: 01/02/1997
4:
jy= 35.0246575342466 37.027397260274
ky= 35.0246575342466 36.0246575342466 37.027397260274
Please provide  4  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2: 1
3: 1
4: 1
5:

Coefficients:
                 Value Std. Error t value Pr(>|t|)
    (Intercept) -0.7009  5.4037    -0.1297  0.8976
        slope.1 -0.1812  0.1556    -1.1649  0.2527
        slope.2  0.5363  0.1925     2.7858  0.0089
        slope.3 -0.5138  0.1198    -4.2887  0.0002
amplitude.sin.1 -0.2894  0.0769    -3.7655  0.0007
amplitude.sin.2  0.2223  0.0999     2.2261  0.0332
amplitude.sin.3 -0.2413  0.0917    -2.6305  0.0130
amplitude.sin.4  0.3791  0.1040     3.6449  0.0009

Overall Corrected AIC=-2.37827985907311


Coefficients:
```

```
                Value Std. Error  t value Pr(>|t|)
(Intercept) -13.3243   1.1808   -11.2844   0.0000
sample.year   0.1838   0.0328     5.6014   0.0000

Corrected AIC for simple linear regression=-1.70520110173896
```



(56) DC94I. There are 40 observations. The final model is given by

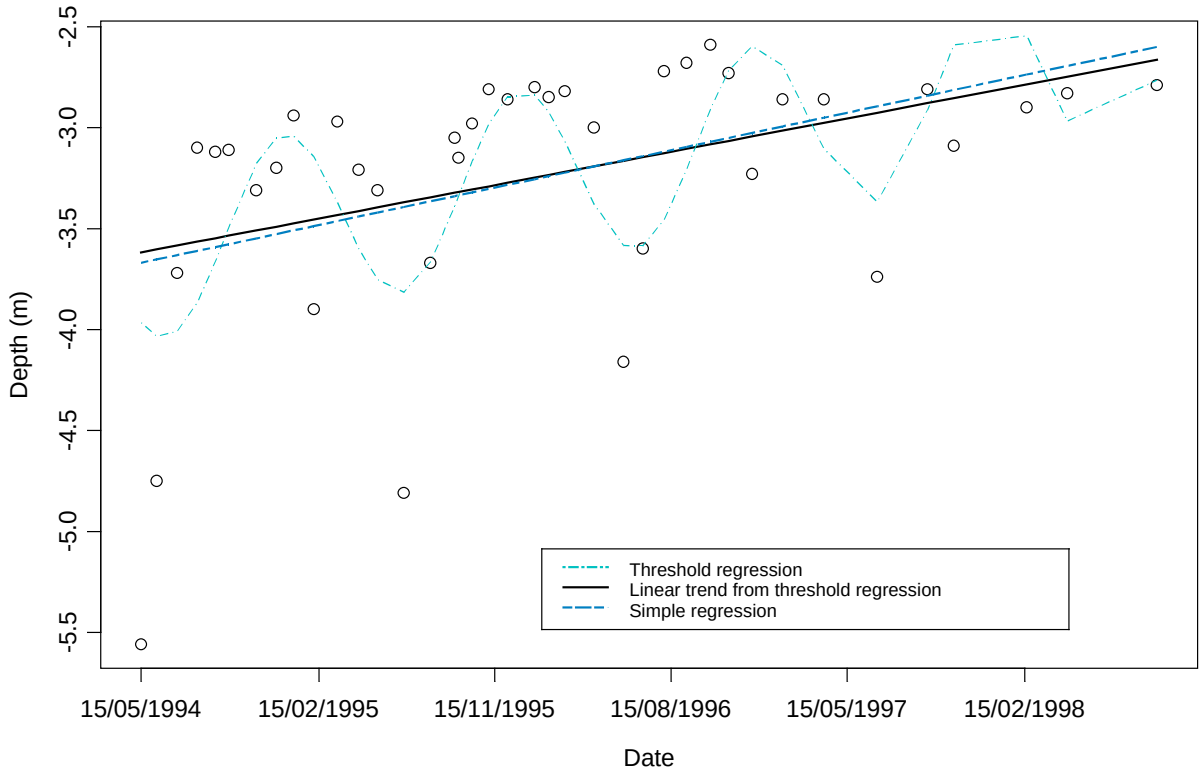
$$x_t = -11.1555 + 0.2208\,t - 0.4464\sin(2\pi t)$$

The estimated linear trend increased at the rate of 22.08cm/year. The simple linear regression is

$$x_t = -12.1237 + 0.2476\,t,$$

giving the estimated rate of increase of 24.76cm/year. The S+ output is below.

```
Coefficients:
                  Value Std. Error  t value Pr(>|t|)
    (Intercept) -11.1555   2.5295    -4.4102   0.0001
        slope.1   0.2208   0.0705     3.1315   0.0034
amplitude.sin.1  -0.4464   0.1181    -3.7809   0.0006
Overall Corrected AIC=-0.230366123946554


Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept) -12.1237   2.9340    -4.1321   0.0002
sample.year   0.2476   0.0818     3.0274   0.0045
Corrected AIC for simple linear regression=0.0661333363018237
```



(57) DC95D. There are 38 observations. The final model is given by

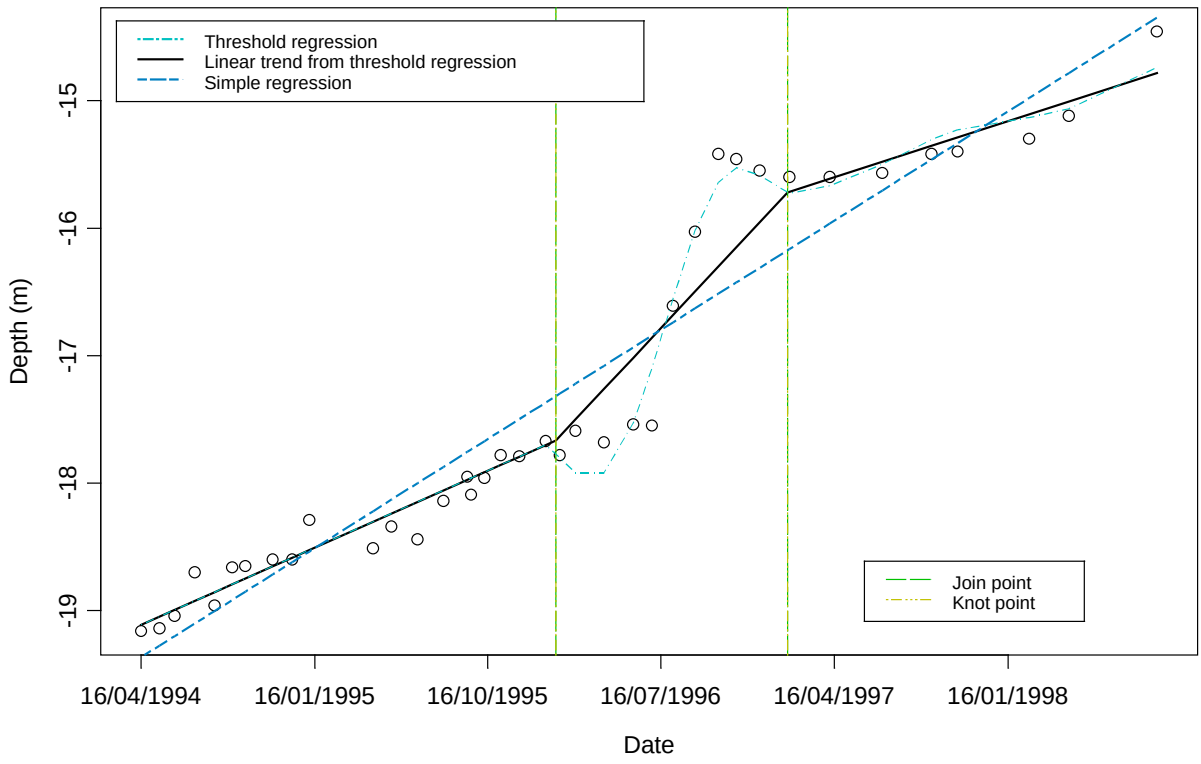
$$x_t = -46.6593 + 0.8049\,t + 1.1341(t - 36.0247)_+ - 1.1353(t - 37.0247)_+ \\ -0.6636\delta_{(t-36.0247)}\sin(2\pi t) + 0.6050\delta_{(t-37.0247)}\sin(2\pi t)$$

where the join and knot points were at 01/02/1996 and 01/02/1997. The estimated linear trend increased at the rate of 80.49cm/year, 193.90cm/year and 80.37cm/year. The simple linear regression is

$$x_t = -58.3733 + 1.1397\,t,$$

giving the estimated rate of increase of 113.97cm/year. The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/02/1996
2: 01/02/1997
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/02/1996
2: 01/02/1997
3:
jy= 36.0246575342466 37.027397260274
ky= 36.0246575342466 37.027397260274
Please provide  3  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 0
2: 1
3: 1
4:

Coefficients:
                  Value Std. Error  t value Pr(>|t|)
    (Intercept) -46.6593   2.1139   -22.0728   0.0000
        slope.1   0.8049   0.0601    13.4030   0.0000
        slope.2   1.1341   0.1642     6.9057   0.0000
        slope.3  -1.3535   0.2064    -6.5571   0.0000
amplitude.sin.2  -0.6636   0.0872    -7.6092   0.0000
amplitude.sin.3   0.6050   0.1248     4.8490   0.0000
Overall Corrected AIC=-2.2313070638353


Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept) -58.3733   2.1446   -27.2192   0.0000
sample.year   1.1397   0.0595    19.1532   0.0000
Corrected AIC for simple linear regression=-0.536911895214397
```


Threshold regression
Linear trend from threshold regression
Simple regression
Join point
Knot point
Depth (m)
-15
-16
-17
-18
-19
16/04/1994
16/01/1995
16/10/1995
16/07/1996
16/04/1997
16/01/1998
Date

(58) DO01D. There are 43 observations. The optimal model is given by

$$x_t = -1.2086 + 0.0511t - 0.3206(t-34.0247)_+ + 0.5381(t-35.0247)_+ - 0.3943(t-37.0247)_+ \\ -0.2142\sin(2\pi t) + 0.1410\delta_{(t-33.0247)}\sin(2\pi t) - 0.2848\delta_{(t-35.0247)}\sin(2\pi t) + 0.2566\delta_{(t-37.0247)}\sin(2\pi t)$$

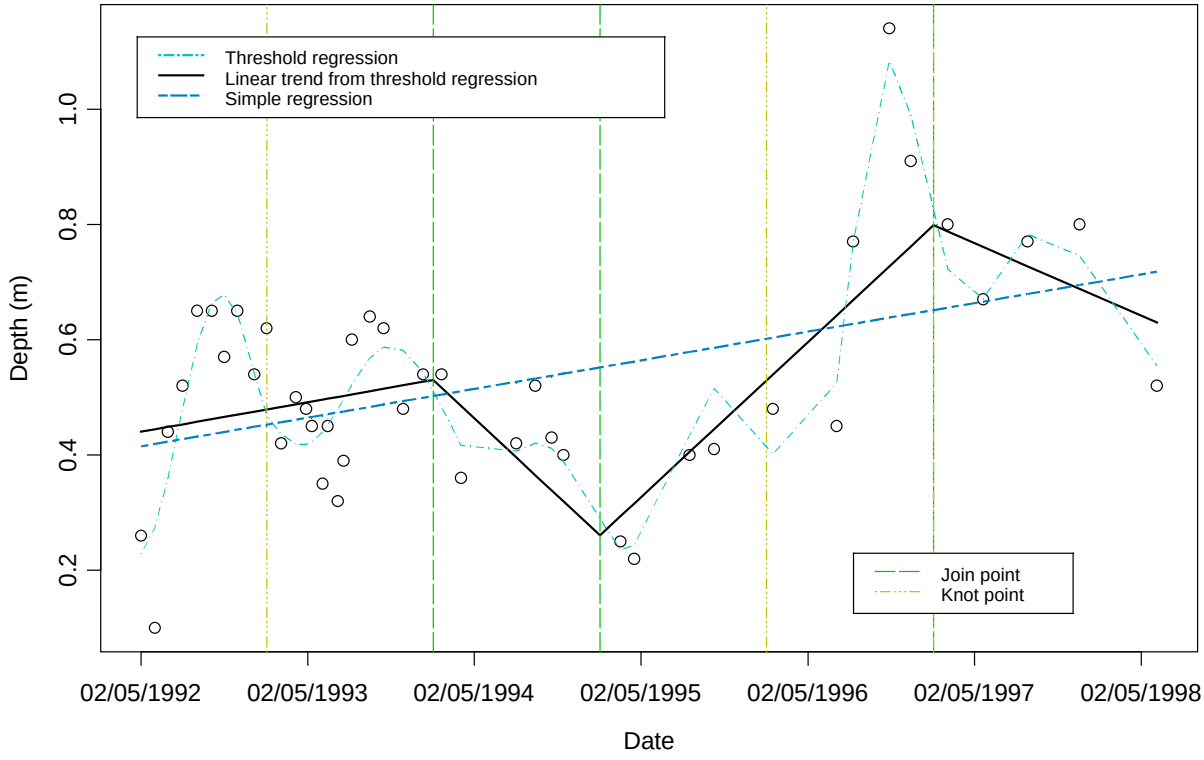
where the joint points were at 01/02/1994 and 01/02/1995, the knot points were at 01/02/1993 and 01/02/1996, the join and knot point was at 01/02/1997. The estimated linear trend increased at the rate of 5.11cm/year (no trend), then decreased at 26.95cm/year, and then increased at 26.86cm/year and finally decreased at 12.57cm/year. The simple linear regression is

$$x_t = -1.1879 + 0.0497\,t\,,$$

giving the estimated rate of increase of 4.97cm/year. The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/02/1994
2: 01/02/1995
3: 01/02/1997
4:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/02/1993
2: 01/02/1996
3: 01/02/1997
4:
jy= 34.0246575342466 35.0246575342466 37.027397260274
ky= 33.0246575342466 36.0246575342466 37.027397260274
Please provide  4  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2: 1
3: 1
4: 1
5:

Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept) -1.2086  1.0296    -1.1739  0.2486
        slope.1  0.0511  0.0310     1.6477  0.1086
        slope.2 -0.3206  0.0769    -4.1669  0.0002
        slope.3  0.5381  0.0815     6.6003  0.0000
        slope.4 -0.3943  0.0891    -4.4239  0.0001
amplitude.sin.1 -0.2142  0.0369    -5.8005  0.0000
amplitude.sin.2  0.1410  0.0439     3.2163  0.0028
amplitude.sin.3 -0.2848  0.0724    -3.9362  0.0004
amplitude.sin.4  0.2566  0.0917     2.7994  0.0084

Overall Corrected AIC=-3.65866196629311
```

```
Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -1.1879  0.5363    -2.2152  0.0324
sample.year  0.0497  0.0155     3.1949  0.0027

Corrected AIC for simple linear regression=-2.36842918594288
```



(59) DO02I. There are 43 observations. The optimal model is given by

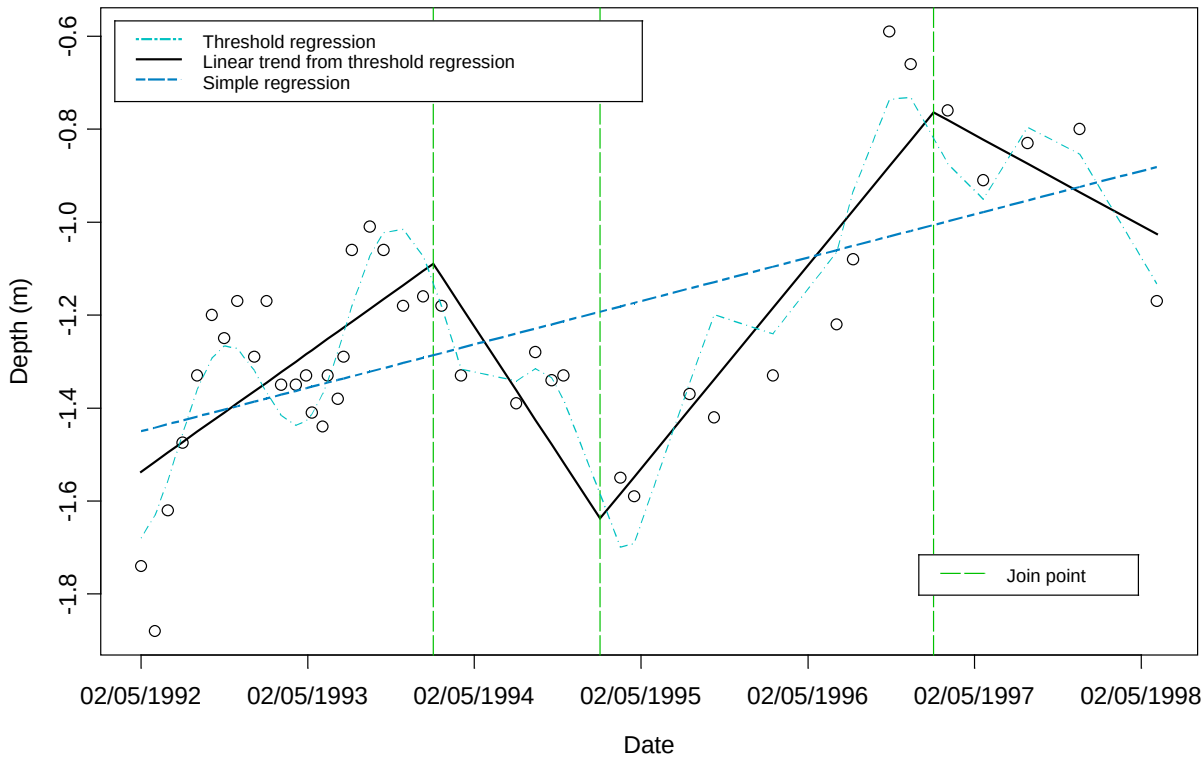
$$x_t = -9.7686 + 0.2551t - 0.8029(t - 34.0247)_+ + 0.9840(t - 35.0247)_+ - 0.6318(t - 37.0247)_+ - 0.1445\sin(2\pi t)$$

where the joint points were at 01/02/1994, 01/02/1995 and 01/02/1997. The estimated linear trend increased at the rate of 25.51cm/year, then decreased at 54.78cm/year, and then increased at 43.62cm/year and finally decreased at 19.56cm/year. The simple linear regression is

$$x_t = -4.4610 + 0.0933t,$$

giving the estimated rate of increase of 9.33cm/year. The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/02/1994
2: 01/02/1995
3: 01/02/1997
4:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1:
jy= 34.0246575342466 35.0246575342466 37.027397260274
Please provide  1  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2:

Coefficients:
                 Value Std. Error t value Pr(>|t|)
    (Intercept) -9.7686  1.3568    -7.1999  0.0000
        slope.1  0.2551  0.0409     6.2408  0.0000
        slope.2 -0.8029  0.1005    -7.9925  0.0000
        slope.3  0.9840  0.1026     9.5913  0.0000
        slope.4 -0.6318  0.1087    -5.8115  0.0000
amplitude.sin.1 -0.1445  0.0229    -6.3131  0.0000

Overall Corrected AIC=-3.24542920628726


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -4.4610  0.6584    -6.7756  0.0000
sample.year  0.0933  0.0191     4.8881  0.0000

Corrected AIC for simple linear regression=-1.95807041927666
```


Threshold regression
Linear trend from threshold regression
Simple regression
Join point
Depth (m)
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
-1.8
02/05/1992
02/05/1993
02/05/1994
02/05/1995
02/05/1996
02/05/1997
02/05/1998
Date

(60) DO03I. There are 42 observations. The starting point is at 01/03/1960. The optimal model is given by

$$x_t = -22.1993 + 0.5183t - 0.5583(t-33.0219)_+ + 0.9333(t-36.0247)_+ - 1.0293(t-37.0247)_+ \\ -0.0904\sin(2\pi t) - 0.1849\delta_{(t-36.0247)}\sin(2\pi t) + 0.2258\delta_{(t-37.0247)}\sin(2\pi t)$$

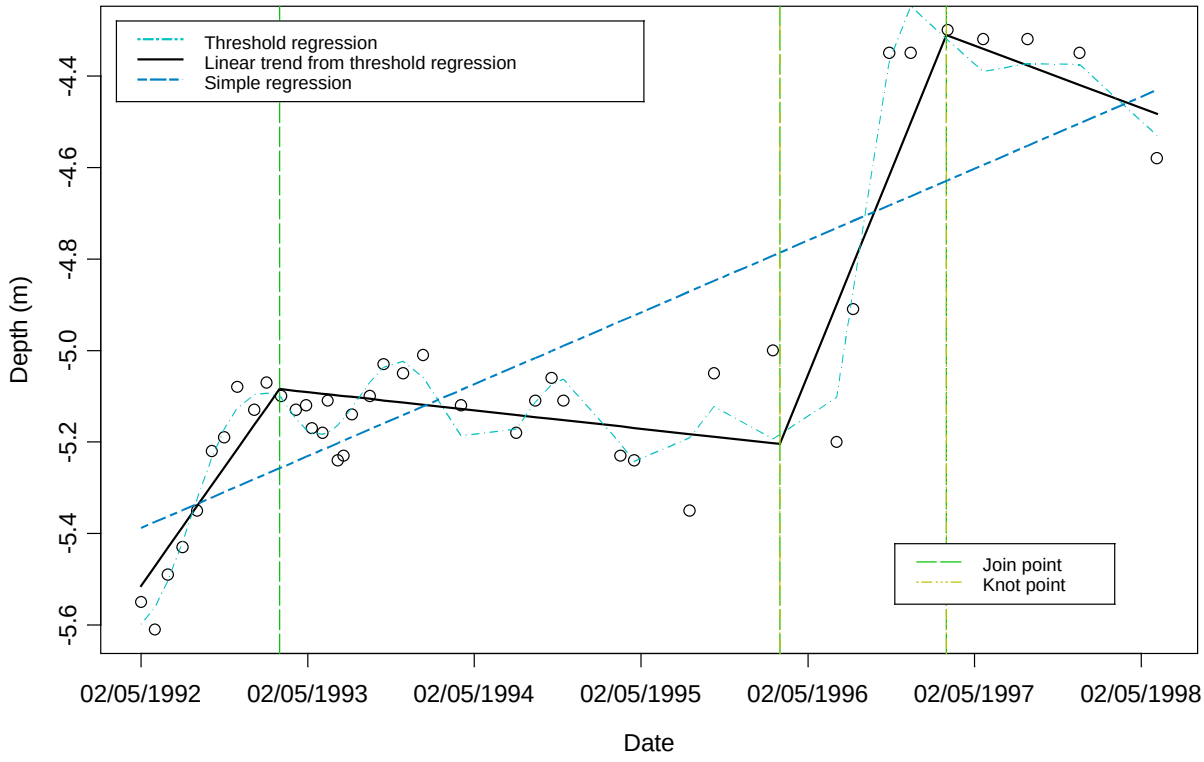
where the joint point was at 01/03/1993, the join and knot points were at 01/03/1996 and 01/03/1997. The estimated linear trend increased at the rate of 51.83/year, then decreased at 4.00cm/year, and then increased at 89.33cm/year and finally decreased at 13.60cm/year. The simple linear regression is

$$x_t = -10.4410 + 0.1570t,$$

giving the estimated rate of increase of 15.70cm/year. The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/03/1993
2: 01/03/1996
3: 01/03/1997
4:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/03/1996
2: 01/03/1997
3:
jy= 33.0219178082192 36.0246575342466 37.0246575342466
ky= 36.0246575342466 37.0246575342466
Please provide  3  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2: 1
3: 1
4:

Coefficients:
                   Value Std. Error  t value Pr(>|t|)
    (Intercept) -22.1993   1.6988   -13.0677   0.0000
        slope.1   0.5183   0.0518    10.0061   0.0000
        slope.2  -0.5583   0.0593    -9.4222   0.0000
        slope.3   0.9333   0.0654    14.2750   0.0000
        slope.4  -1.0293   0.1034    -9.9526   0.0000
amplitude.sin.1  -0.0904   0.0164    -5.5146   0.0000
amplitude.sin.2  -0.1849   0.0495    -3.7364   0.0007
amplitude.sin.3   0.2258   0.0638     3.5386   0.0012

Overall Corrected AIC=-4.11373464650522
```

```
Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept) -10.4410   0.6248   -16.7113   0.0000
sample.year   0.1570   0.0181     8.6485   0.0000

Corrected AIC for simple linear regression=-2.05653707406267
```



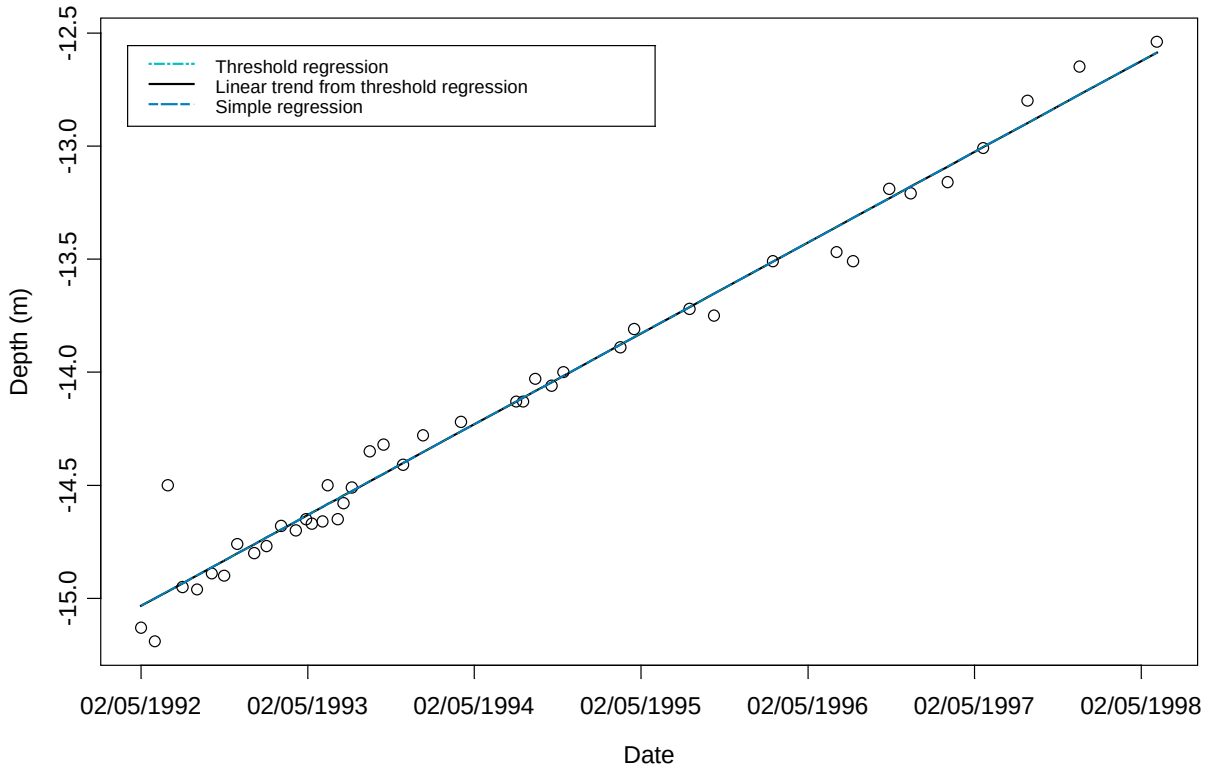
(61) DO04D. No analysis can be done as many data are –5.90.

(62) DO05D. There are 43 observations. The optimal model is the simple linear regression given by

$$x_t = -27.9781 + 0.4012t$$

which gives the estimated rate of increase of 40.12cm/year. The S+ output is below.

```
Coefficients:
                Value Std. Error  t value Pr(>|t|)
(Intercept) -27.9781   0.3211   -87.1434   0.0000
sample.year   0.4012   0.0093    43.1122   0.0000

Overall Corrected AIC =-3.39616987981118
```



(63) DO06I. No analysis can be done as many data are –11.68.

(64) DO07D. There are 43 observations. The starting point is at 01/01/1960. The optimal model is given by

$$x_t = -1.4335 - 0.0463t + 0.1522(t - 35.0247)_+ - 0.2158(t - 37.0247)_+ \\ -0.1020\sin(2\pi t)$$

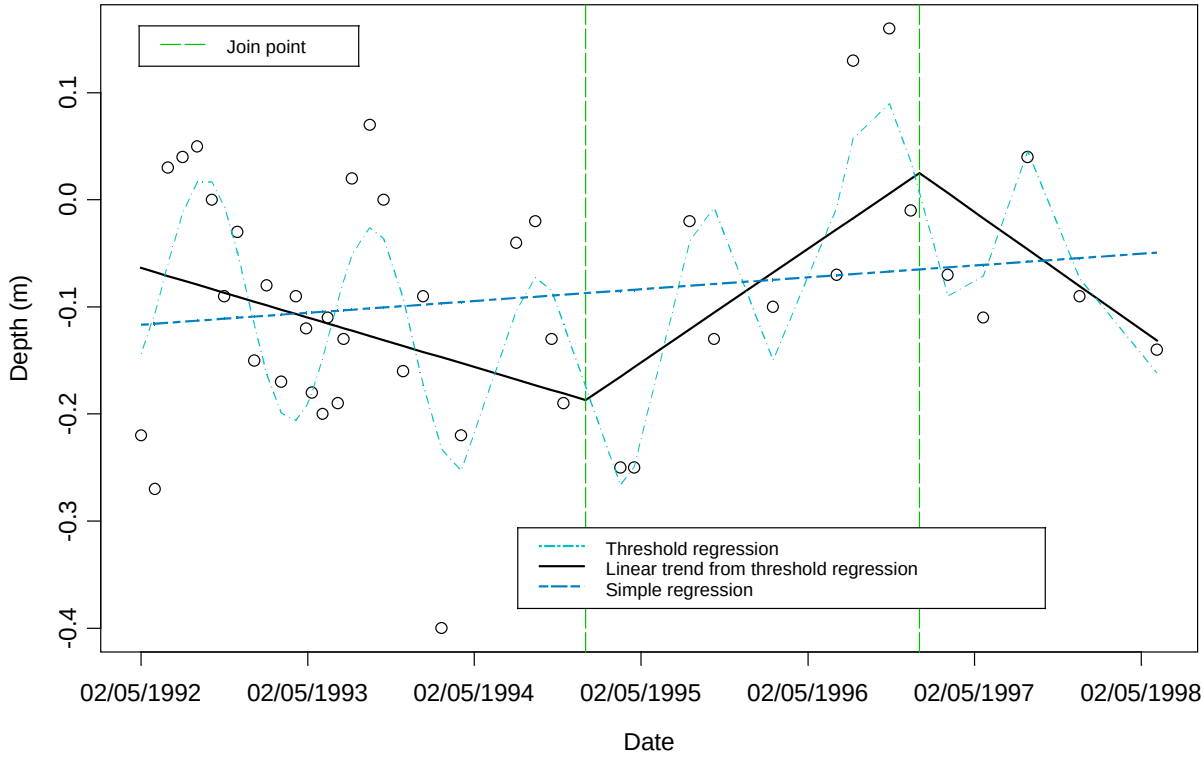
where the joint points were at 01/01/1995 and 01/01/1997. The estimated linear trend decreased at the rate of 4.63cm/year (no trend), then increased at 10.59cm/year, and then decreased at 10.99cm/year. The simple linear regression is

$$x_t = -0.4741 + 0.0110t,$$

giving the estimated rate of increase of 1.10cm/year (no trend). The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/01/1995
2: 01/01/1997
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1:
jy= 35.0246575342466 37.027397260274
Please provide  1  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2:

Coefficients:
                 Value Std. Error t value Pr(>|t|)
    (Intercept)  1.4335  0.5530     2.5923  0.0135
        slope.1 -0.0463  0.0165    -2.8120  0.0077
        slope.2  0.1522  0.0363     4.1912  0.0002
        slope.3 -0.2158  0.0676    -3.1932  0.0028
amplitude.sin.1 -0.1020  0.0158    -6.4737  0.0000

Overall Corrected AIC=-4.02392002398975

Statistical Summary for Linear Regression Model


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -0.4741  0.3474    -1.3647  0.1798
sample.year  0.0110  0.0100     1.0996  0.2779
```

Corrected AIC for simple linear regression=-3.24171211918047



(65) DO08D. There are 42 observations. The starting point is at 01/01/1960. The optimal model is given by

$$x_t = \begin{cases} -8.8524 + 0.2028\,t - 0.3086(t - 33.0247)_+ + 0.1867(t - 35.0247)_+ & \\ \quad -0.2440\sin(2\pi t) + 0.1511\delta_{(t-33.0247)}\sin(2\pi t) & t \le 36.5315 \\ -0.8480 - 0.3399\,t - 0.1203\sin(2\pi t) & t > 36.5315 \end{cases}$$

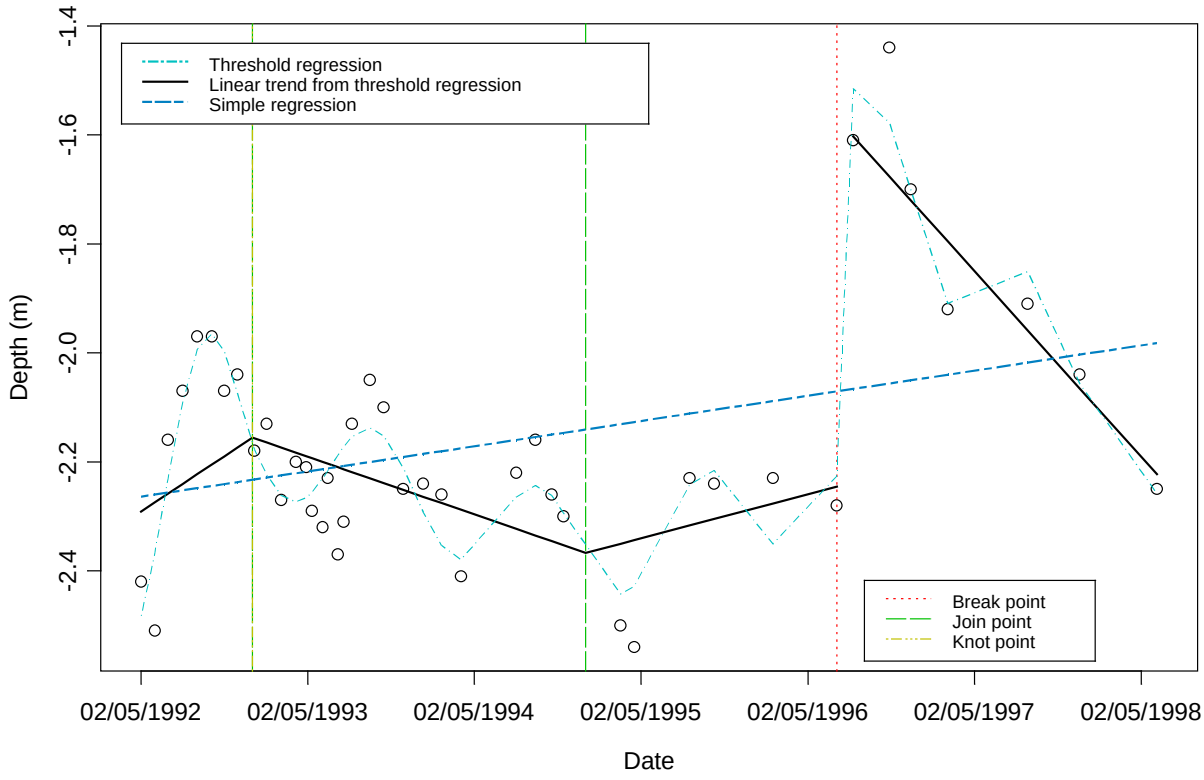
where the break was 04/07/1996, the joint point was at 01/01/1995, the join and knot point was at 01/01/1995. The estimated linear trend increased at the rate of 20.28cm/year, then decreased at 10.58cm/year, and then increased at 8.09cm/year. After a size of jump of 4.58cm, the estimated linear trend decreased again at the rate of 33.99cm/year. The simple linear regression is

$$x_t = -3.7590 + 0.0462\,t,$$

giving the estimated rate of increase of 4.62cm/year. The S+ output is below.

```
input break dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A break date is a date at which all the trend changes)
1: 04/07/1996
2:
by= 36.5315068493151

input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/01/1993
2: 01/01/1995
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/01/1993
2:
jy= 33.0246575342466 35.0246575342466
ky= 33.0246575342466
Please provide  2  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2: 1
3:

Coefficients:
                 Value Std. Error t value Pr(>|t|)
    (Intercept) -8.8524  2.9021    -3.0503  0.0048
        slope.1  0.2028  0.0884     2.2928  0.0293
        slope.2 -0.3086  0.1057    -2.9207  0.0067
        slope.3  0.1867  0.0703     2.6547  0.0128
amplitude.sin.1 -0.2440  0.0442    -5.5145  0.0000
amplitude.sin.2  0.1511  0.0511     2.9576  0.0061

Corrected AIC for this segment=  -3.73227368228273
```

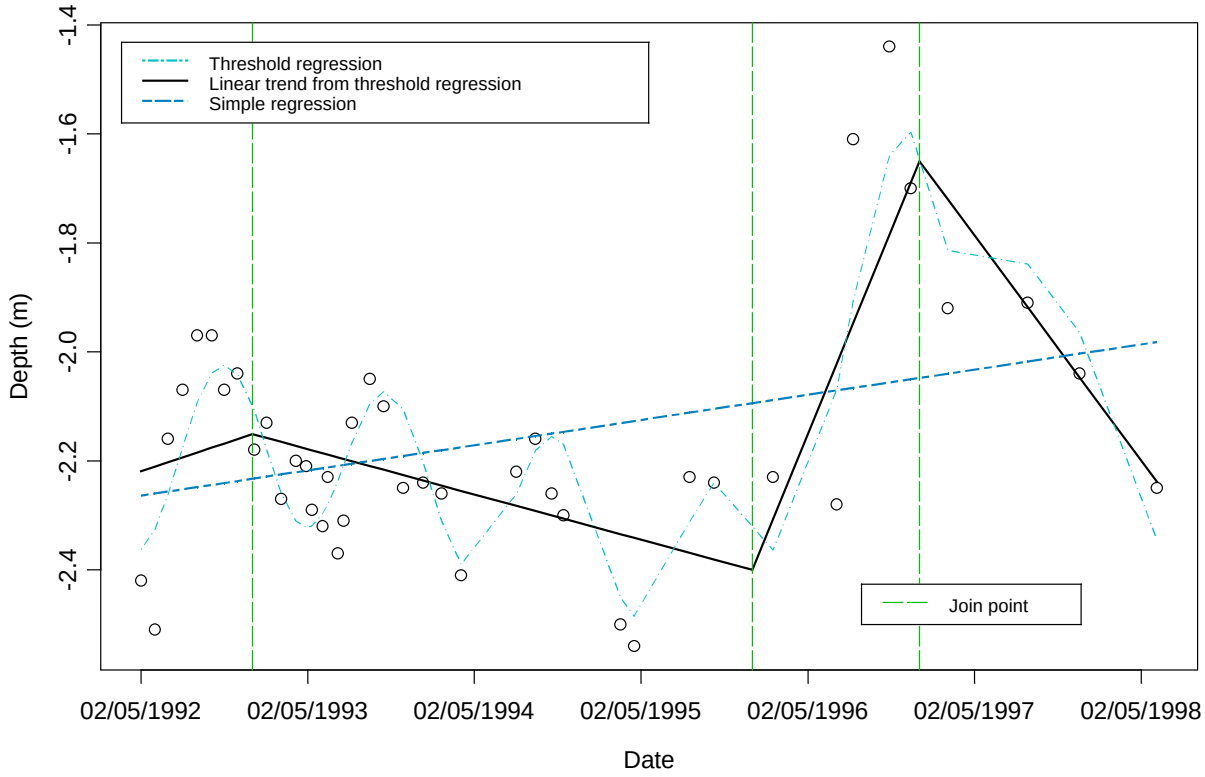
```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1:
Please provide  1  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2:

Coefficients:
                  Value Std. Error  t value Pr(>|t|)
    (Intercept)  10.8480   2.1828     4.9697   0.0077
        slope.1  -0.3399   0.0583    -5.8346   0.0043
amplitude.sin.1  -0.1203   0.0574    -2.0960   0.1041

Corrected AIC for this segment=  -0.391314366002771

Overall Corrected AIC=-3.62772240633983


Coefficients:
             Value Std. Error t value Pr(>|t|)
(Intercept) -3.7590  0.6731    -5.5845  0.0000
sample.year  0.0462  0.0195     2.3687  0.0228

Corrected AIC for simple linear regression=-1.98129202085383
```



For a comparison, we also fit the following model:

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/01/1993
2: 01/01/1996
3: 01/01/1997
4:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1:
jy= 32.9397260273973 35.9397260273973 36.9424657534247
Please provide  1  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2:

Coefficients:
```

```
                 Value Std. Error t value Pr(>|t|)
    (Intercept) -5.5014  3.8340    -1.4349  0.1599
        slope.1  0.1017  0.1170     0.8694  0.3904
        slope.2 -0.1847  0.1295    -1.4262  0.1624
        slope.3  0.8307  0.1059     7.8445  0.0000
        slope.4 -1.1603  0.1560    -7.4386  0.0000
amplitude.sin.1 -0.1450  0.0249    -5.8348  0.0000

Overall Corrected AIC=-3.12576618750902
```



(66) DO09D. There are 40 observations. The optimal model is given by

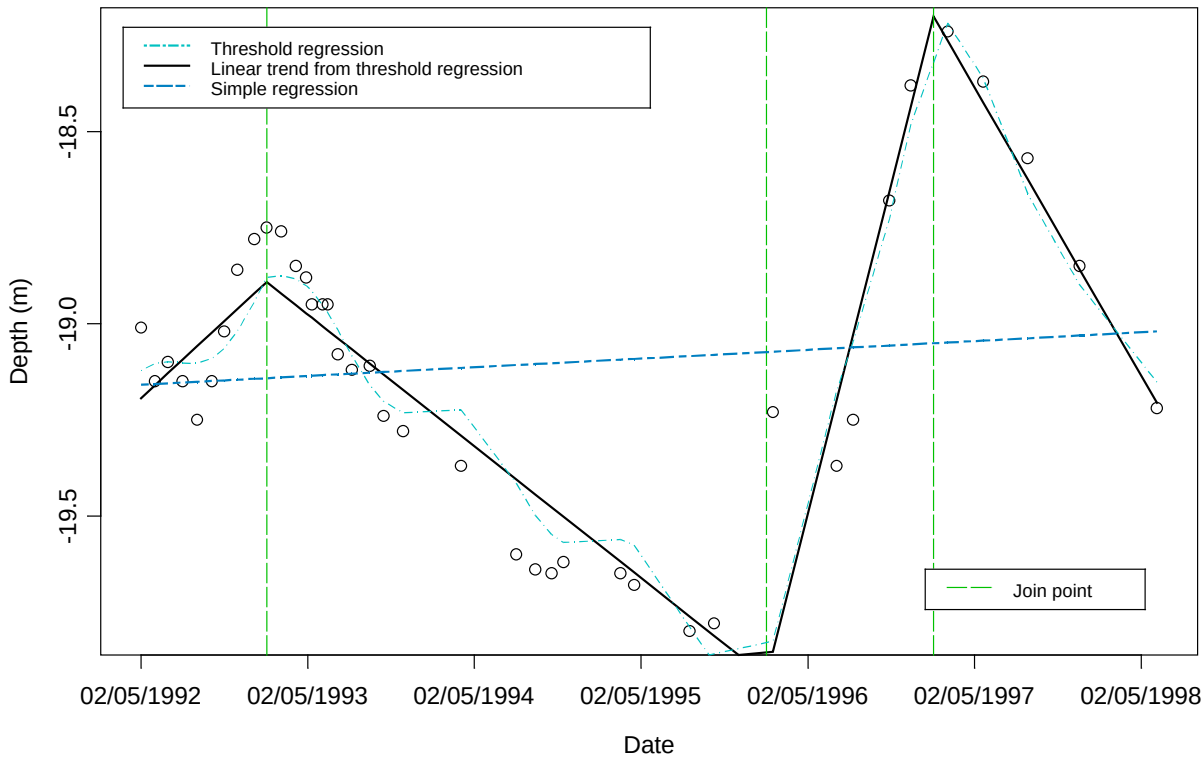
$$x_t = -32.1274 + 0.4008t - 0.7436(t - 33.0247)_+ + 2.0572(t - 36.0247)_+ - 2.4644(t - 37.0247)_+ \\ -0.0717\sin(2\pi t)$$

where the joint points were at 01/02/1993, 01/02/1996 and 10/02/1997. The estimated linear trend increased at the rate of 40.08cm/year, then decreased at 34.28cm/year, and then increased at 171.44cm/year and finally decreased at 75.00cm/year. The simple linear regression is

$$x_t = -19.8919 + 0.0277t,$$

giving the estimated rate of increase of 2.77cm/year (no trend). The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/02/1993
2: 01/02/1996
3: 01/02/1997
4:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1:
jy= 33.0246575342466 36.0246575342466 37.027397260274
Please provide  1  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2:

Coefficients:
                  Value Std. Error  t value Pr(>|t|)
    (Intercept) -32.1274   4.3489    -7.3875   0.0000
        slope.1   0.4008   0.1325     3.0242   0.0047
        slope.2  -0.7436   0.1495    -4.9749   0.0000
        slope.3   2.0572   0.1368    15.0337   0.0000
        slope.4  -2.4644   0.2098   -11.7457   0.0000
amplitude.sin.1   0.0717   0.0317     2.2598   0.0304
Overall Corrected AIC=-2.57703320543878


Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept) -19.8919   1.2154   -16.3665   0.0000
sample.year   0.0227   0.0352     0.6454   0.5225

Corrected AIC for simple linear regression=-0.735032701770107
```


Threshold regression
Linear trend from threshold regression
Simple regression
Join point
Depth (m)
-18.5
-19.0
-19.5
02/05/1992
02/05/1993
02/05/1994
02/05/1995
02/05/1996
02/05/1997
02/05/1998
Date

(67) DO100I. There are 14 observations. The starting point is at 01/03/1960. The optimal model is given by

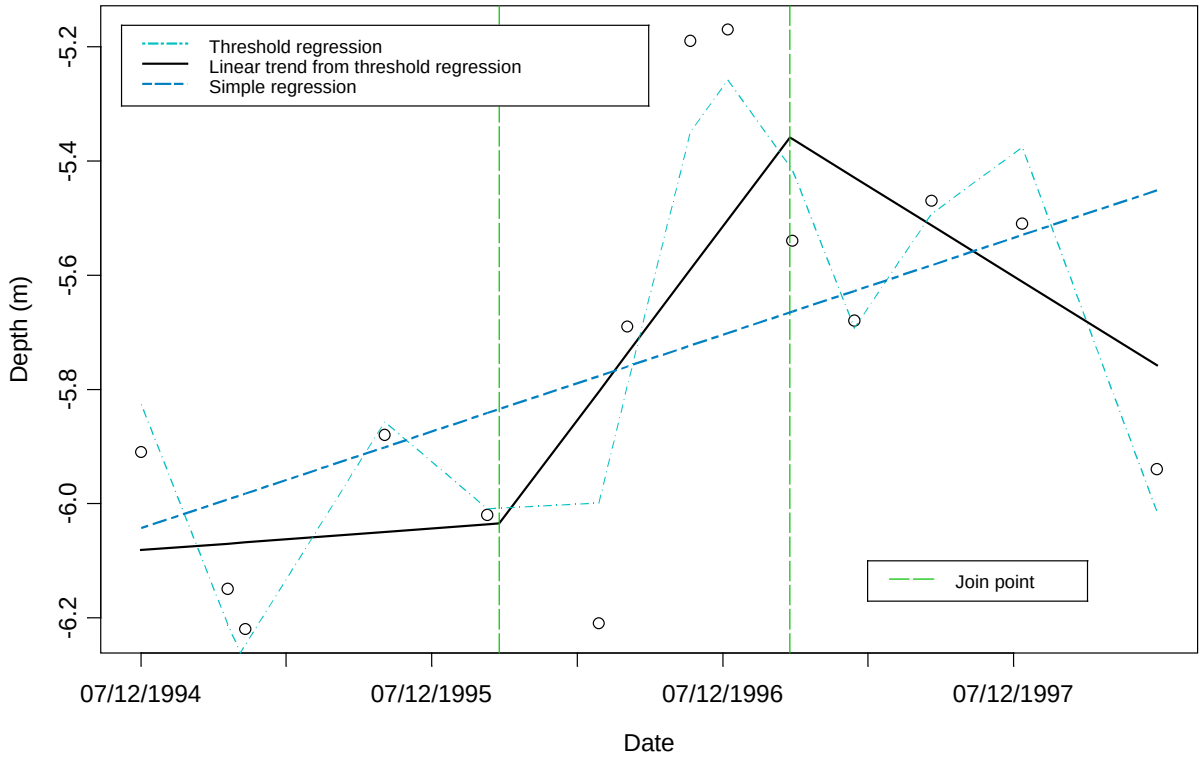
$$x_t = -7.3939 + 0.0377t + 0.6386(t - 36.0247)_+ - 0.9918(t - 37.0247)_+ \\ -0.2643\sin(2\pi t)$$

where the joint points were at 01/03/1996 and 01/03/1997. The estimated linear trend increased at the rate of 3.77cm/year and 6763cm/year before decreasing at 31.55cm/year. The simple linear regression is

$$x_t = -11.9325 + 0.1693t,$$

giving the estimated rate of increase of 16.93cm/year. The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/03/1996
2: 01/03/1997
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1:
jy= 36.0246575342466 37.0246575342466
Please provide  1  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2:

Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept) -7.3939  4.1111    -1.7985  0.1056
        slope.1  0.0377  0.1161     0.3250  0.7526
        slope.2  0.6383  0.2276     2.8047  0.0206
        slope.3 -0.9918  0.2182    -4.5454  0.0014
amplitude.sin.1 -0.2643  0.0471    -5.6117  0.0003

Overall Corrected AIC=-1.86617799354893


Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept) -11.9325   2.9597    -4.0316   0.0017
sample.year   0.1693   0.0811     2.0878   0.0588

Corrected AIC for simple linear regression=-0.816023906952867
```


Threshold regression
Linear trend from threshold regression
Simple regression
Join point
Depth (m)
-5.2
-5.4
-5.6
-5.8
-6.0
-6.2
07/12/1994
07/12/1995
07/12/1996
07/12/1997
Date

(68) DO101I. There are 14 observations. The starting point is at 01/03/1960. The optimal model is given by

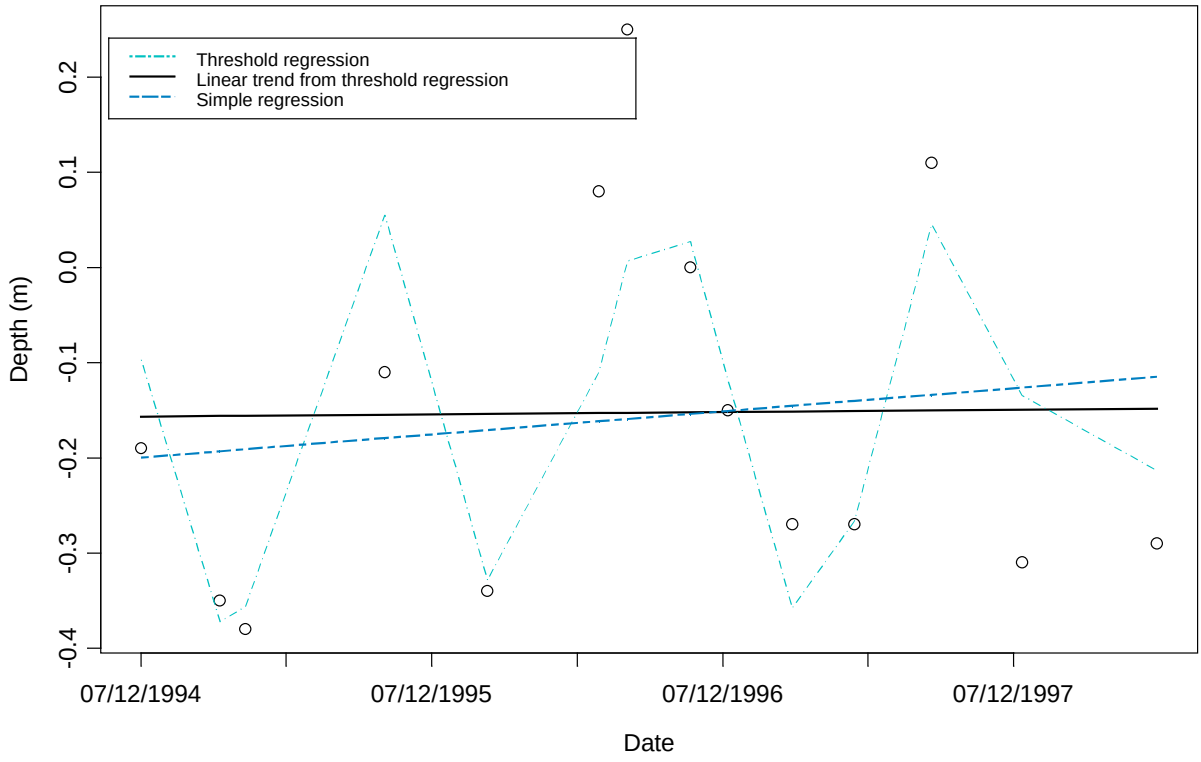
$$x_t = -0.2385 + 0.0023t - 0.2083\sin(2\pi t)$$

There is no linear trend in water levels. The simple linear regression is

$$x_t = -1.0473 + 0.0242t,$$

showing also no trend in water levels. The S+ output is below.

```
Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept) -0.2385  1.2429    -0.1919  0.8513
        slope.1  0.0023  0.0339     0.0691  0.9461
amplitude.sin.1 -0.2183  0.0500    -4.3658  0.0011

Overall Corrected AIC=-2.44966996004364


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -1.0473  1.9452    -0.5384  0.6001
sample.year  0.0242  0.0530     0.4571  0.6558

Corrected AIC for simple linear regression=-1.65914527646506
```


Threshold regression
Linear trend from threshold regression
Simple regression
Depth (m)
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
07/12/1994
07/12/1995
07/12/1996
07/12/1997
Date

(69) DO18D. There are 30 observations. I suspect that the bore is dried up frequently as 18 observations are –1.83. No analysis has been done.

(70) DO20D. There are 29 observations. I suspect that the bore is dried up frequently as 26 observations are –1.83. No analysis has been done.

(71) DO22D. There are 30 observations. The starting point is 01/01/1960. The optimal model is given by

$$x_t = -11.9095 + 0.2540\,t - 0.8434(t - 36.0247)_+ \\ -1.0315\delta_{(t-25.0247)}\sin(2\pi t) + 1.1024\delta_{(t-27.0247)}\sin(2\pi t)$$

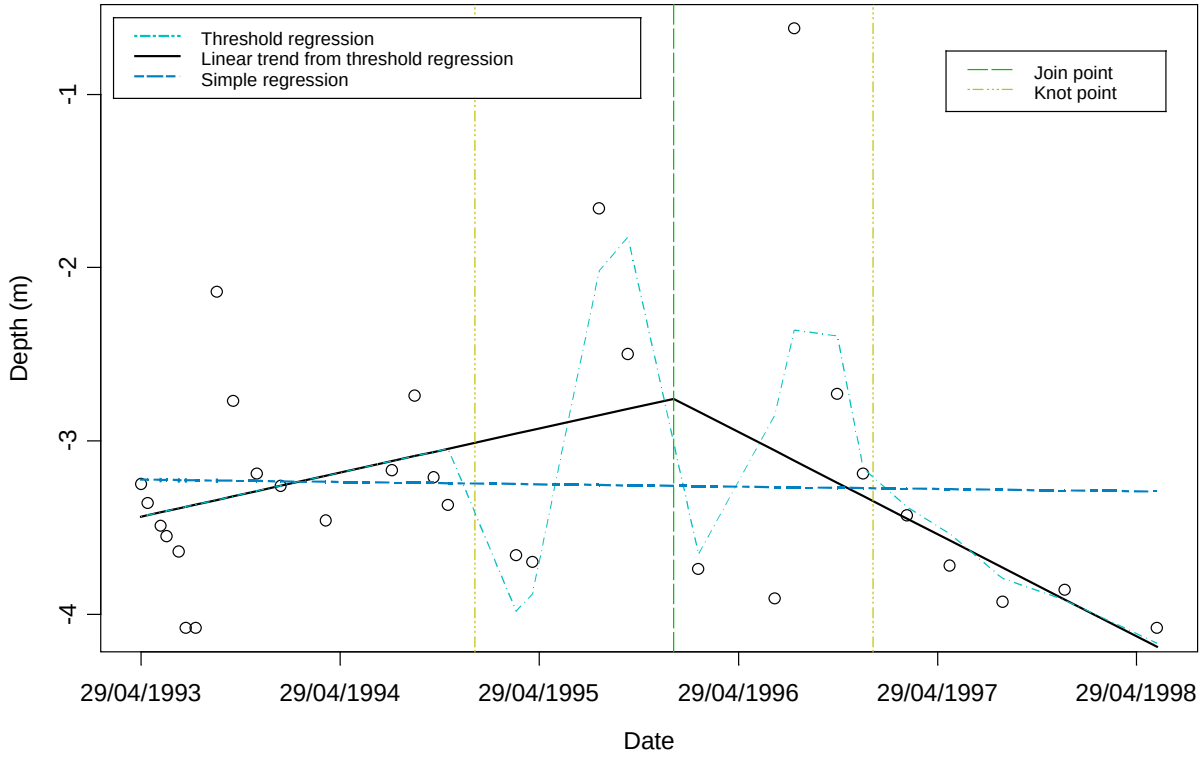
where the joint point was at 01/01/1996 and the knot points were at 01/01/1995 and 10/01/1997. The estimated linear trend increased at the rate of 25.40cm/year and then decreased at 58.94cm/year. The simple linear regression is

$$x_t = -2.7726 - 0.0135t,$$

giving the estimated rate of increase of 1.35cm/year (no trend). The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/01/1996
2:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/01/1995
2: 01/01/1997
3:
jy= 36.0246575342466
ky= 35.0246575342466 37.027397260274
Please provide  3  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 0
2: 1
3: 1
4:

Coefficients:
                  Value Std. Error  t value Pr(>|t|)
    (Intercept) -11.9095   4.5510    -2.6169   0.0148
        slope.1   0.2540   0.1320     1.9240   0.0658
        slope.2  -0.8434   0.3068    -2.7492   0.0109
amplitude.sin.2  -1.0315   0.2531    -4.0748   0.0004
amplitude.sin.3   1.1024   0.4834     2.2805   0.0314

Overall Corrected AIC=0.231915472905544
```

```
Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -2.7726  3.1572    -0.8782  0.3873
sample.year -0.0135  0.0895    -0.1513  0.8809

Corrected AIC for simple linear regression=0.671269731955196
```



(72) DO24D. There are 29 observations. I suspect that the bore is dried up frequently as 19 observations are –4.61. No analysis has been done.

(73) DO26D. There are 30 observations. The starting point is 01/01/1960. The optimal model is given by

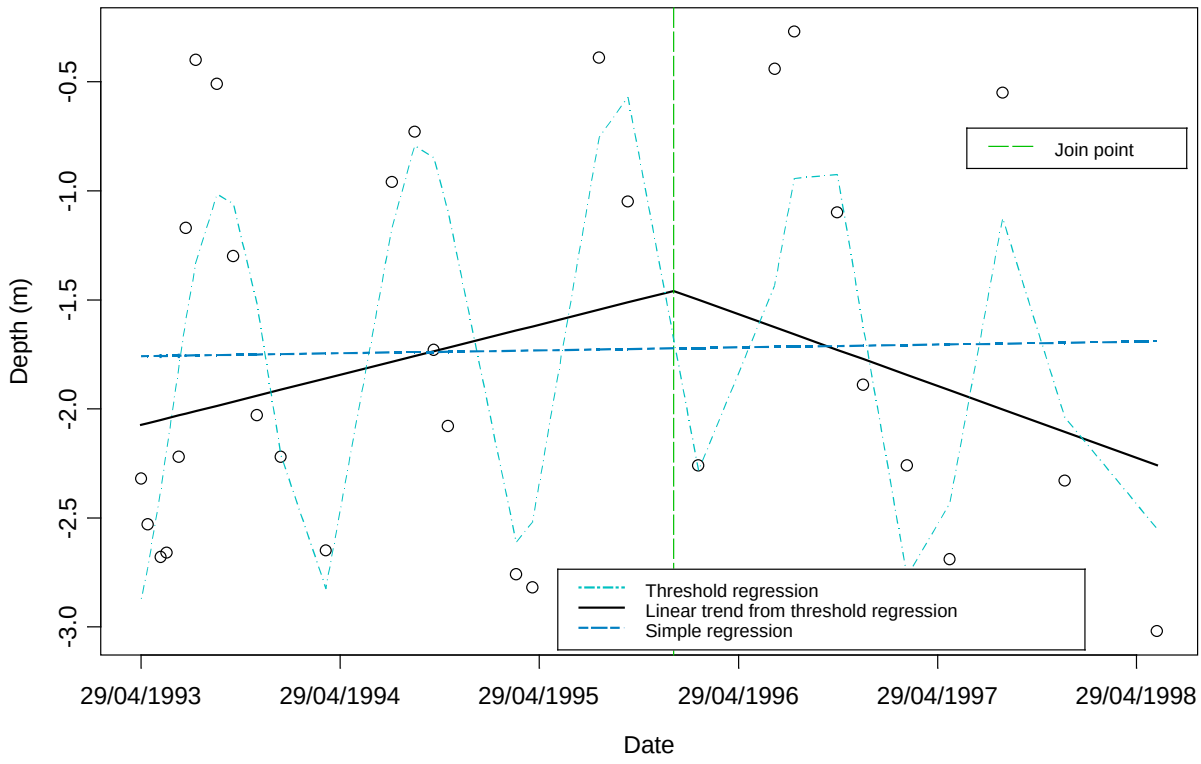
$$x_t = -9.7330 + 0.2297t - 0.5592(t - 36.0247)_+ \\ -0.9787\sin(2\pi t)$$

where the joint point was at 01/01/1996. The estimated linear trend increased at the rate of 22.97cm/year and then decreased at 32.95cm/year. The simple linear regression is

$$x_t = -2.2016 + 0.0133t,$$

giving the estimated rate of increase of 1.33cm/year (no trend). The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/01/1996
2:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1:
jy= 36.0246575342466
Please provide  1  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2:

Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept) -9.7330  4.1679    -2.3352  0.0275
        slope.1  0.2297  0.1210     1.8986  0.0688
        slope.2 -0.5592  0.2838    -1.9705  0.0595
amplitude.sin.1 -0.9787  0.1394    -7.0215  0.0000

Overall Corrected AIC=-0.00129190772925236


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept) -2.2016  3.7399    -0.5887  0.5608
sample.year  0.0133  0.1060     0.1252  0.9013

Corrected AIC for simple linear regression=1.00998973108519
```


Depth (m)
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
29/04/1993
29/04/1994
29/04/1995
29/04/1996
29/04/1997
29/04/1998
Date
Join point
Threshold regression
Linear trend from threshold regression
Simple regression

(74) DO28D. There are 30 observations. The starting point is 01/03/1960. The optimal model is given by

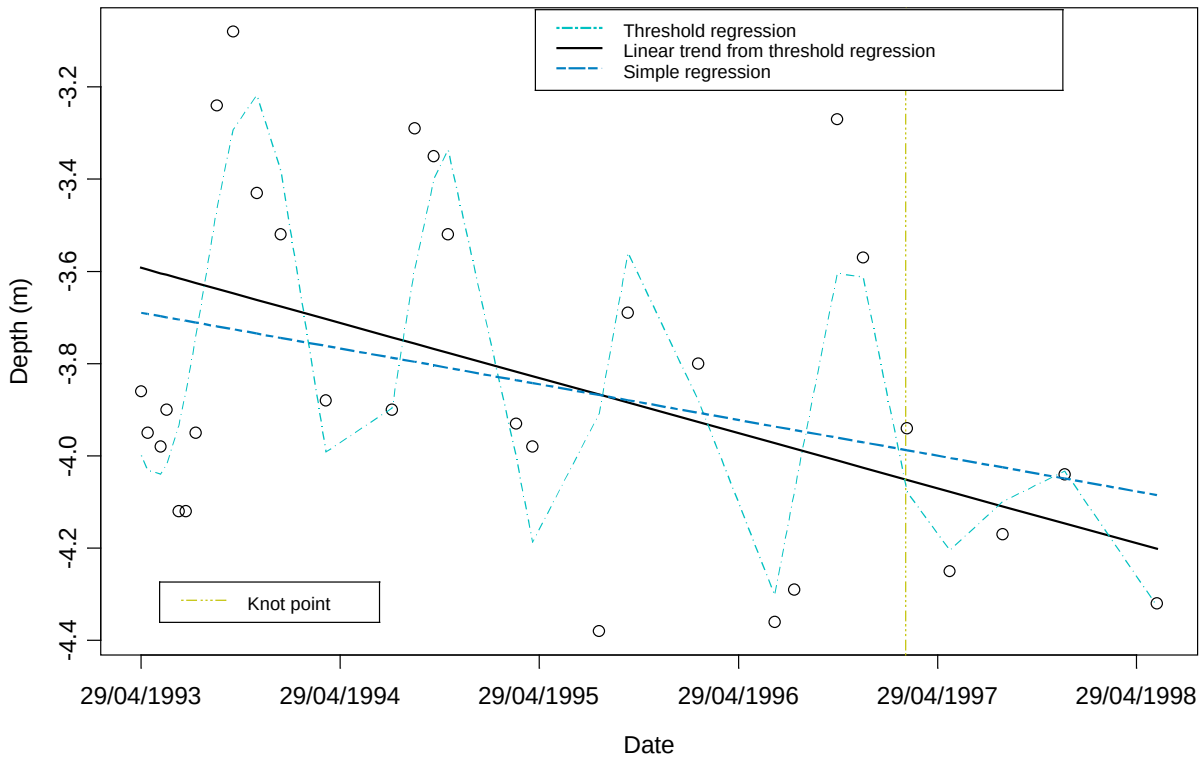
$$x_t = 0.3711 - 0.1194t - 0.4449\sin(2\pi t) + 0.3176\delta_{(t-37.0247)}\sin(2\pi t)$$

where the knot point was at 01/03/1997. The estimated linear trend decreased at the rate of 11.94cm/year. The simple linear regression is

$$x_t = -1.1196 - 0.0775t,$$

giving the estimated rate of decrease of 7.75cm/year (no trend). The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/03/1997
2:
ky= 37.0246575342466
Please provide  2  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2: 1
3:

Coefficients:
                 Value Std. Error t value Pr(>|t|)
    (Intercept)  0.3711  0.8365     0.4436  0.6610
        slope.1 -0.1194  0.0238    -5.0079  0.0000
amplitude.sin.1 -0.4449  0.0562    -7.9139  0.0000
amplitude.sin.2  0.3176  0.1349     2.3552  0.0263

Overall Corrected AIC=-2.01413340108627


Coefficients:
             Value Std. Error t value Pr(>|t|)
(Intercept) -1.1196  1.4214    -0.7877  0.4375
sample.year -0.0775  0.0405    -1.9130  0.0660
Corrected AIC for simple linear regression=-0.915472973080878
```


Threshold regression
Linear trend from threshold regression
Simple regression
Knot point
Depth (m)
-3.2
-3.4
-3.6
-3.8
-4.0
-4.2
-4.4
29/04/1993
29/04/1994
29/04/1995
29/04/1996
29/04/1997
29/04/1998
Date

(75) DO30D. There are 30 observations, 21 of which have the value of –2.02. No analysis has been done.

(76) DO32D. There are 29 observations, all of which have the value of –4.95. No analysis has been done.

(77) DO38D. There are 30 observations, 23 of which have the value of –1.20. No analysis has been done.

(78) DO40D. There are 30 observations, all of which have the value of –2.82. No analysis has been done.

(79) DO42D. There are 29 observations. There are 8 observations having the value of –2.47 which means that the bore was dried up. Low sampling frequency restricts the analysis. The starting point is 01/12/1960. We only fit the following model

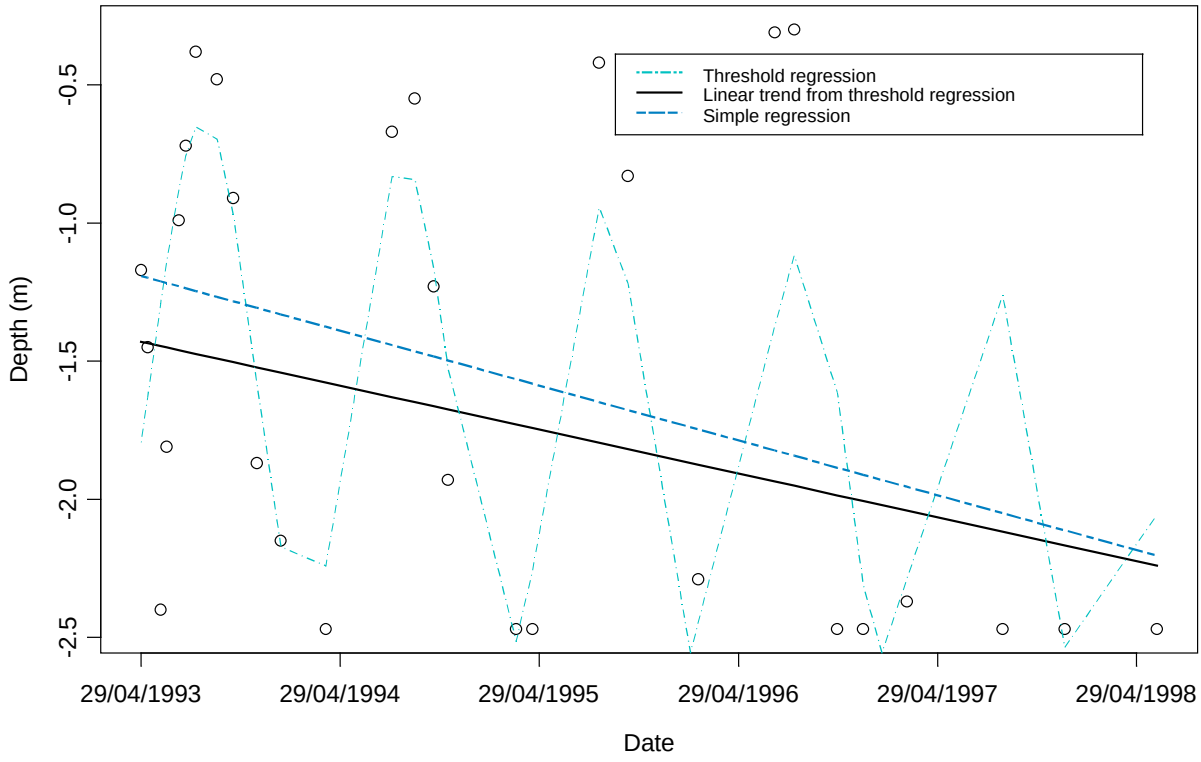
$$x_t = 3.7181 - 0.1587t - 0.8571\sin(2\pi t)$$

giving the estimated rate of decrease of 15.97cm/year. The simple linear regression is

$$x_t = 5.2405 - 0.1983t$$

giving the estimated rate of decrease of 19.83cm/year. The S+ output is below.

```
Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept)  3.7181  2.2722     1.6364  0.1138
        slope.1 -0.1587  0.0662    -2.3982  0.0239
amplitude.sin.1 -0.8571  0.1500    -5.7127  0.0000

Overall Corrected AIC=0.0165508053321248


Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  5.2405  3.3253     1.5759  0.1267
sample.year -0.1983  0.0970    -2.0445  0.0508

Corrected AIC for simple linear regression=0.771539808573622
```


Threshold regression
Linear trend from threshold regression
Simple regression
Depth (m)
-0.5
-1.0
-1.5
-2.0
-2.5
29/04/1993
29/04/1994
29/04/1995
29/04/1996
29/04/1997
29/04/1998
Date

(80) DO50D. There are 30 observations. The optimal model is given by

$$x_t = \begin{cases} -1.3993 - 0.1398\,t + 0.3943(t - 35.0247)_+ - 0.1310\sin(2\pi t) & t \le 36.4658 \\ 71.1299 - 0.1730\,t & t > 36.4658 \end{cases}$$

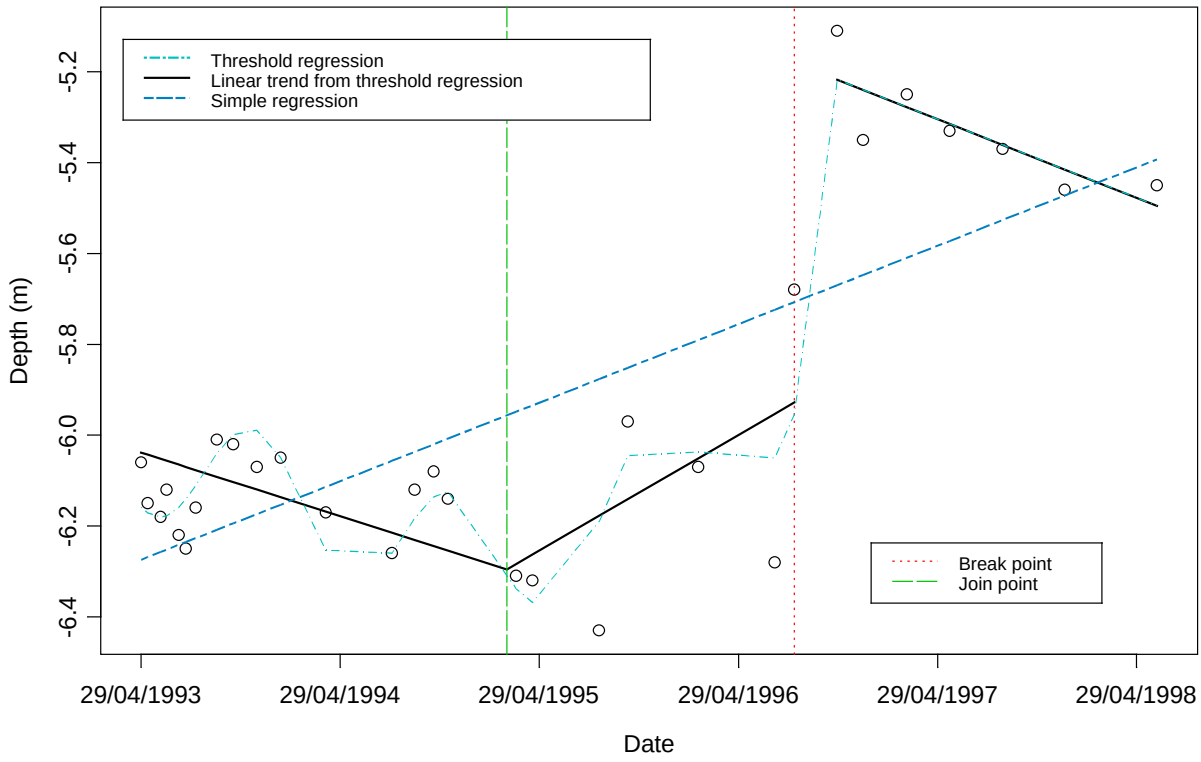
where the break point was at 09/08/1996, the join point was at 01/03/1995. The estimated linear trend decreased at the rate of 13.98cm/year, then increased at 25.45cm/year, then had a jump of 71.08cm followed by a rate of decrease of 17.30cm/year. The simple linear regression is

$$x_t = -12.0045 + 0.1727\,t,$$

giving the estimated rate of decrease of 17.27cm/year (no trend). The S+ output is below.

```
input break dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A break date is a date at which all the trend changes)
1: 09/08/1996
2:
by= 36.4657534246575
The program is now in the interactive graphic mode
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/03/1995
2:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1:
jy= 35.0219178082192
Please provide  1  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2:
Statistical Summary for all data

Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept) -1.3993  1.5358    -0.9111  0.3736
        slope.1 -0.1398  0.0452    -3.0938  0.0060
        slope.2  0.3943  0.1065     3.7030  0.0015
amplitude.sin.1 -0.1310  0.0382    -3.4301  0.0028


The program is now in the interactive graphic mode
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1:
```

```
Please provide   1   numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 0
2:

Coefficients:
              Value Std. Error t value Pr(>|t|)
(Intercept)  1.1299  2.0172     0.5602  0.5995
    slope.1 -0.1730  0.0540    -3.2035  0.0239
Corrected AIC for this segment=  -2.49130238742131

Overall Corrected AIC=-3.04190413431379


Coefficients:
               Value Std. Error  t value Pr(>|t|)
(Intercept) -12.0045   1.0519   -11.4118   0.0000
sample.year   0.1727   0.0300     5.7632   0.0000

Corrected AIC for simple linear regression=-1.51750389050044
```

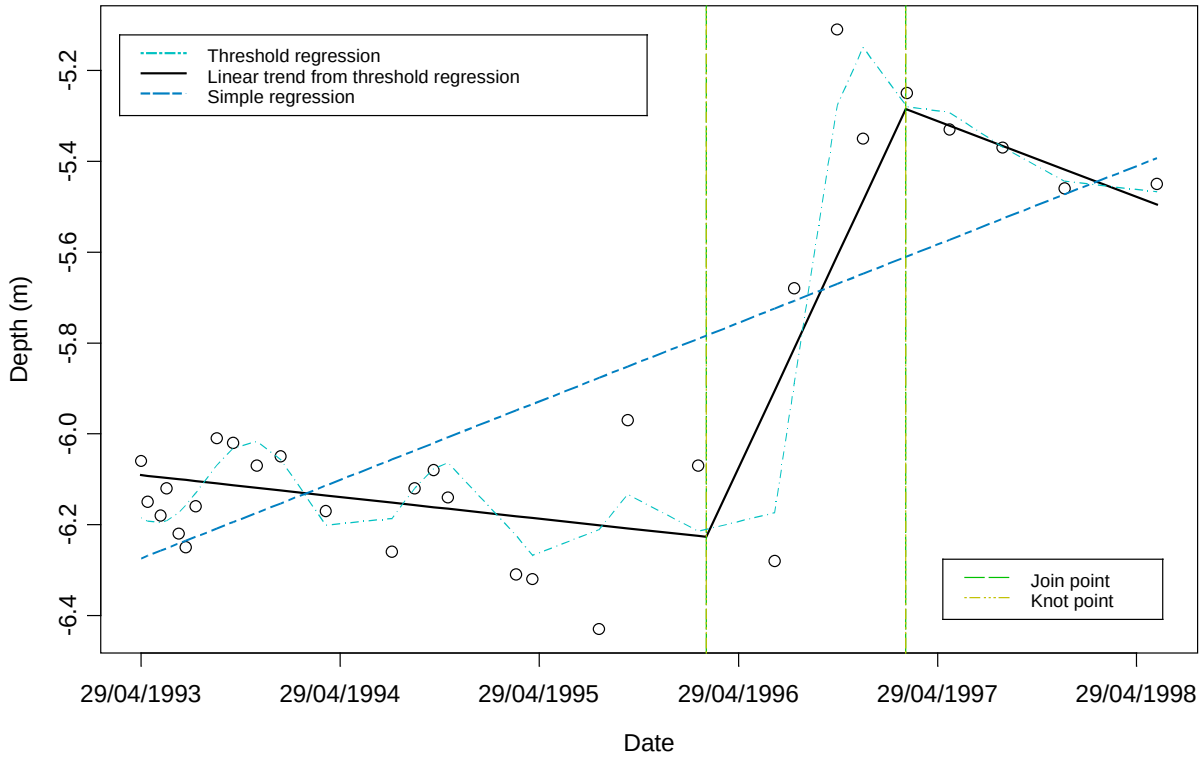


For a comparison, we also fit the following model:

$$x_t = -4.5005 - 0.0479\,t + 0.9901(t - 36.0247)_+ - 1.1089(t - 37.0347)_+ \\ -0.1021\sin(2\pi t) - 0.2610\,\delta_{(t-36.0247)}\sin(2\pi t) + 0.3922\,\delta_{(t-37.0247)}\sin(2\pi t)$$

where the join and knot points are at 01/03/1996 and 01/03/1997. The water levels decrease at 4.79cm/year, then increase at 94.22cm/year and finally decrease at 16.67cm/year. The S+ output is below.

```
input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/03/1996
2: 01/03/1997
3:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1: 01/03/1996
2: 01/03/1997
3:
jy= 36.0246575342466 37.0246575342466
ky= 36.0246575342466 37.0246575342466
Please provide  3  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2: 1
3: 1
4:

Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept) -4.5005  0.9624    -4.6764  0.0001
        slope.1 -0.0479  0.0281    -1.7074  0.1012
        slope.2  0.9901  0.1187     8.3393  0.0000
        slope.3 -1.1089  0.1795    -6.1764  0.0000
amplitude.sin.1 -0.1021  0.0369    -2.7712  0.0109
amplitude.sin.2 -0.2610  0.0887    -2.9425  0.0073
amplitude.sin.3  0.3922  0.1092     3.5910  0.0015

Overall Corrected AIC=-2.89582736625136
```


Threshold regression
Linear trend from threshold regression
Simple regression
Join point
Knot point
Depth (m)
-5.2
-5.4
-5.6
-5.8
-6.0
-6.2
-6.4
29/04/1993
29/04/1994
29/04/1995
29/04/1996
29/04/1997
29/04/1998
Date

(81) DO52D. There are 30 observations. The model fit is

$$x_t = \begin{cases} -2.4815 - 0.0992t + 0.2687(t - 35.0493)_+ - 0.1059\sin(2\pi t) & t \le 36.4658 \\ -2.1195 - 0.0788t & t > 36.4658 \end{cases}$$

where the break point was at 09/08/1996, the join point was at 01/02/1995. The estimated linear trend decreased at the rate of 9.92cm/year, and then increased at 16.95cm/year, then has a jump of 71.81cm followed by a rate of decrease of 7.88cm/year. The simple linear regression is

$$x_t = -11.7996 + 0.1751t,$$

giving the estimated rate of decrease of 17.51cm/year . The S+ output is below.

```
input break dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A break date is a date at which all the trend changes)
1: 09/08/1996
2:
by= 36.5452054794521

input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1: 01/02/1995
2:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1:
jy= 35.0493150684932
Please provide  1  numbers indexing needs of periodic trend for
segments seperated by knot points
1 for yes, 0 for no, [return] or [enter] to finish
1: 1
2:

Coefficients:
                  Value Std. Error t value Pr(>|t|)
    (Intercept) -2.4815  1.5651    -1.5855  0.1294
        slope.1 -0.0992  0.0460    -2.1543  0.0443
        slope.2  0.2687  0.1023     2.6262  0.0166
amplitude.sin.1 -0.1059  0.0353    -3.0027  0.0073

Corrected AIC for this segment=  -2.90950732450919

input join dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A join date is a date at which the slope changes)
1:
input knot dates dd/mm/yyyy (eg 31/01/1990), blank line to finish
(A knot date is a date at which the amplitude changes)
1:
Please provide  1  numbers indexing needs of periodic trend for
segments seperated by knot points
```

```
1 for yes, 0 for no, [return] or [enter] to finish
1: 0
2:

Coefficients:
             Value Std. Error t value Pr(>|t|)
(Intercept) -2.1195  0.9088    -2.3320  0.0670
    slope.1 -0.0778  0.0243    -3.2028  0.0239

Overall Corrected AIC=-3.11023689600514

-5.69679250291533-(-4.97864635978692)
[1] -0.7181461

Coefficients:
              Value Std. Error  t value Pr(>|t|)
(Intercept) -11.7996   0.9909   -11.9077   0.0000
sample.year   0.1751   0.0282     6.2172   0.0000

Corrected AIC for simple linear regression=-1.64153371931429
```