

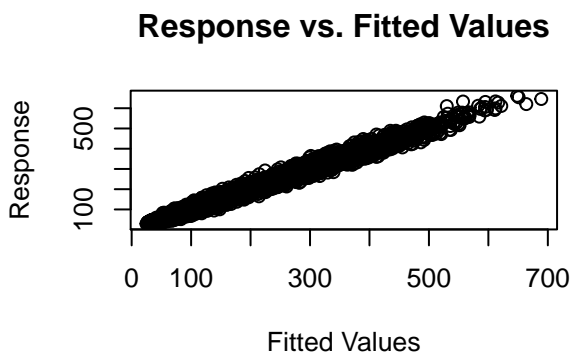
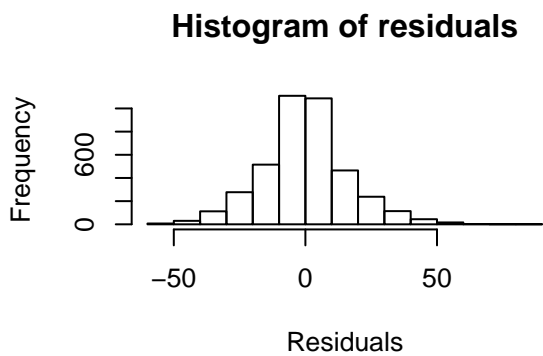
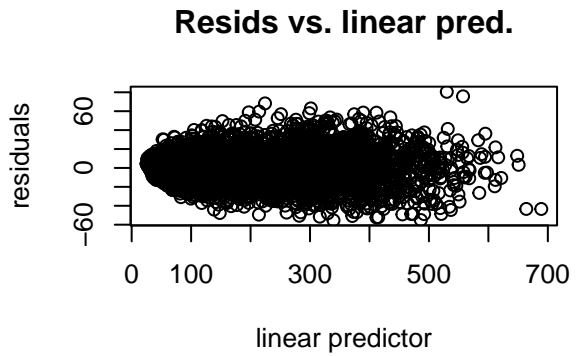
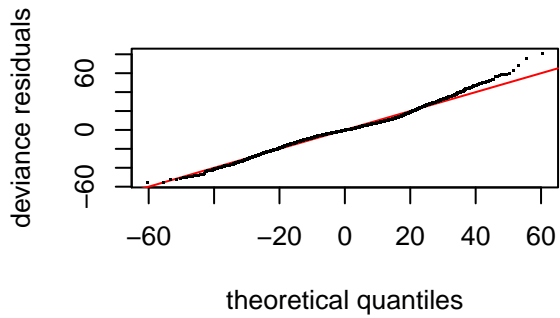
# External appendix B

Elisa Ribesse

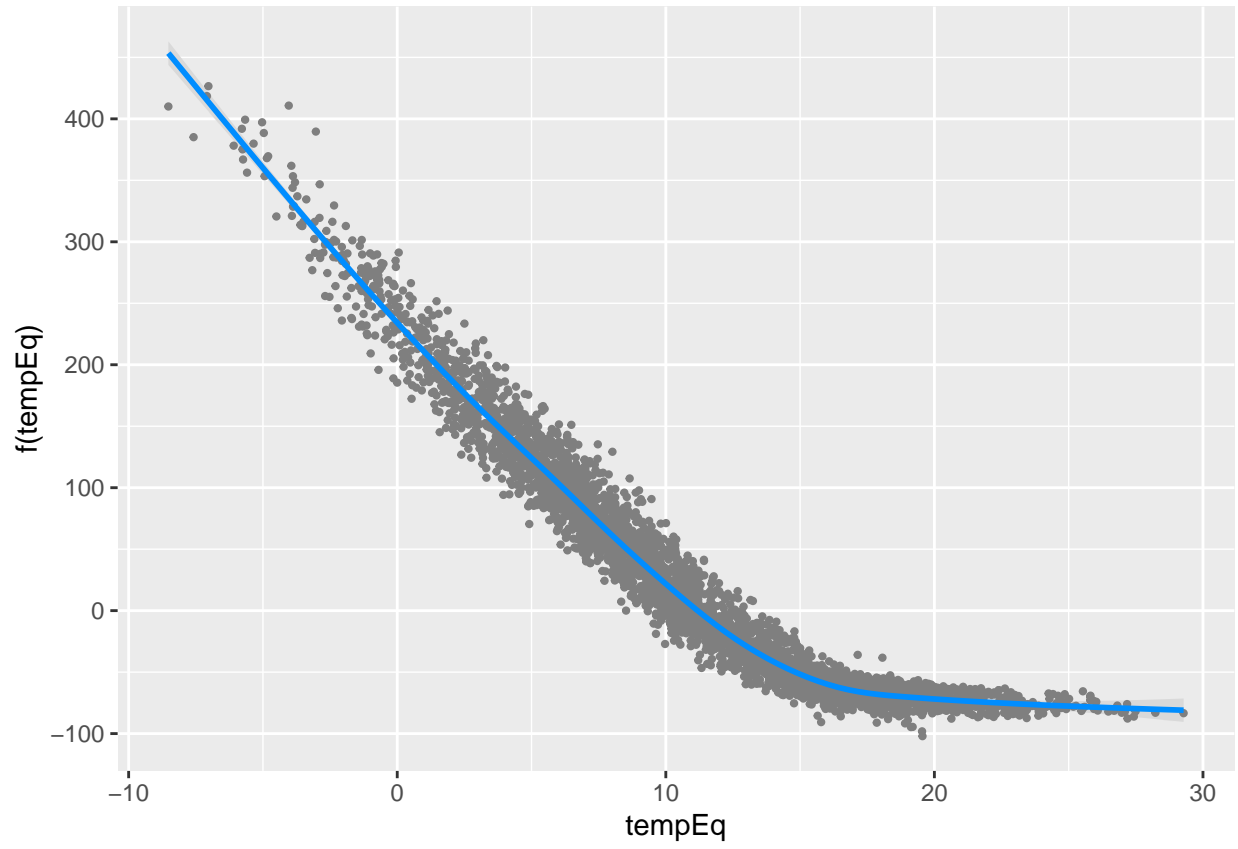
## Looking for a good model for gas:

### Main effects

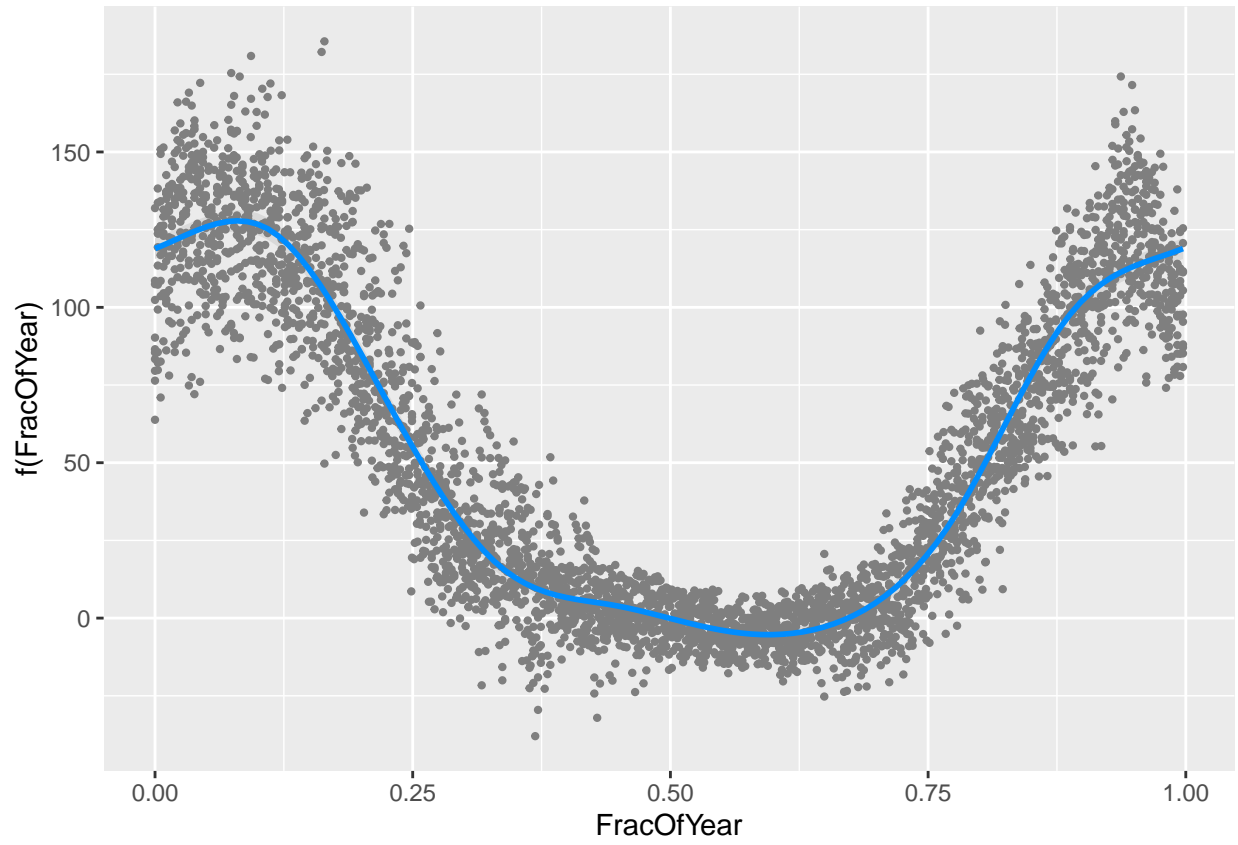
```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## GWhGaz ~ s(tempEq, bs = "cr") + s(FracOfYear, bs = "cc") + s(trend,
##   bs = "cr")
##
## Parametric coefficients:
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept)  190.13      0.26   731.3  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##           edf Ref.df      F p-value
## s(tempEq)   8.285  8.823 4646.21 <2e-16 ***
## s(FracOfYear) 7.932  8.000 1042.97 <2e-16 ***
## s(trend)    7.562  8.479   30.56 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =  0.987   Deviance explained = 98.7%
## -REML = 17008   Scale est. = 271.61    n = 4018
```



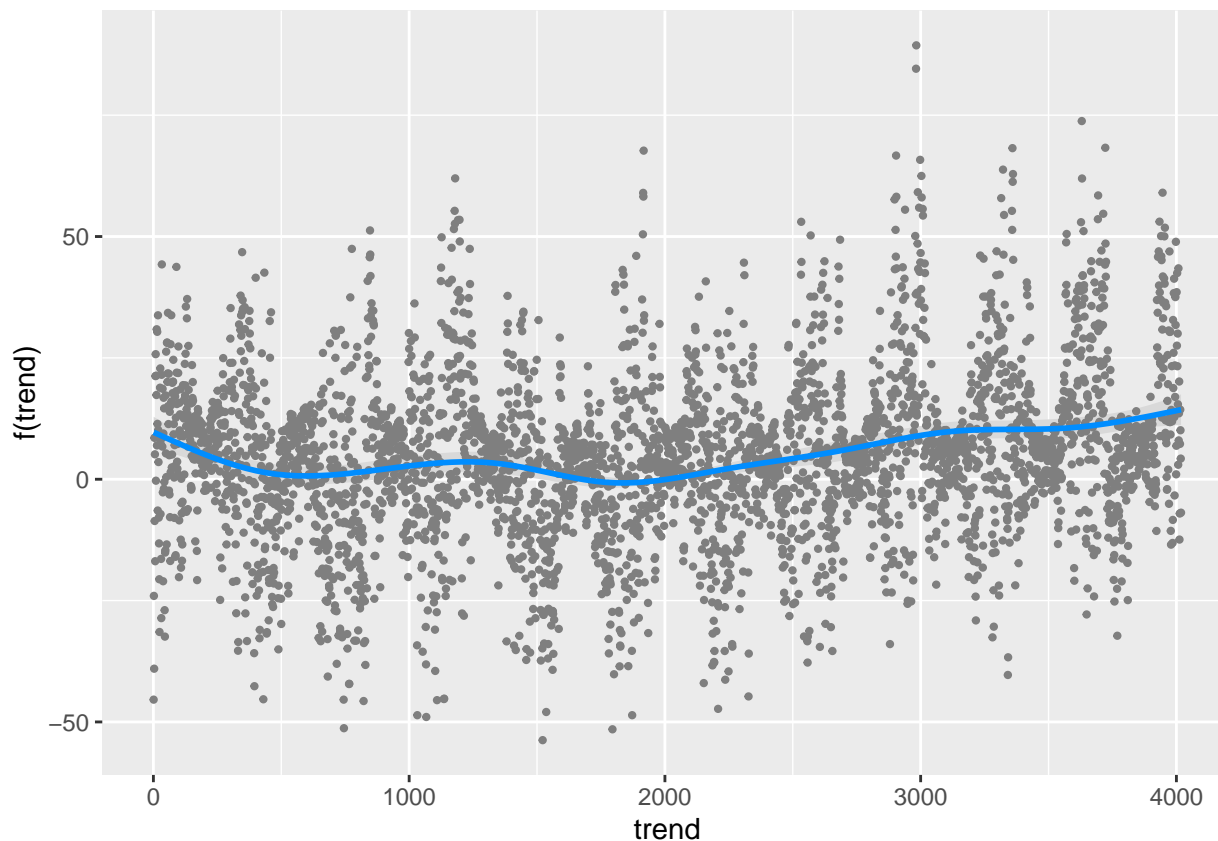
```
##
## Method: REML   Optimizer: outer newton
## full convergence after 5 iterations.
## Gradient range [-0.005543534,0.005389171]
## (score 17008.15 & scale 271.6073).
## Hessian positive definite, eigenvalue range [2.100371,2007.525].
## Model rank = 27 / 27
##
## Basis dimension (k) checking results. Low p-value (k-index<1) may
## indicate that k is too low, especially if edf is close to k'.
##
##           k'  edf k-index p-value
## s(tempEq)   9.00 8.29   1.01   0.81
## s(FracOfYear) 8.00 7.93   0.99   0.29
## s(trend)     9.00 7.56   0.37 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## [[1]]
```



```
##  
## [[2]]
```

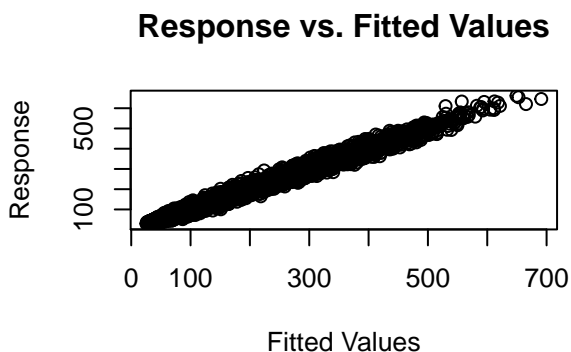
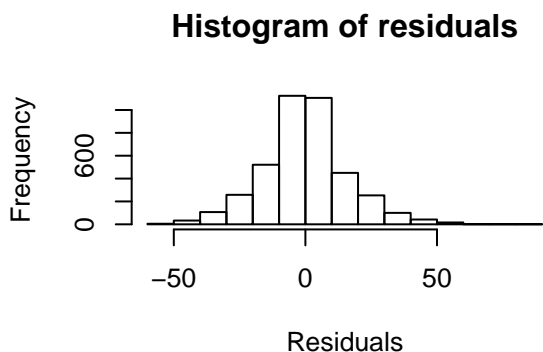
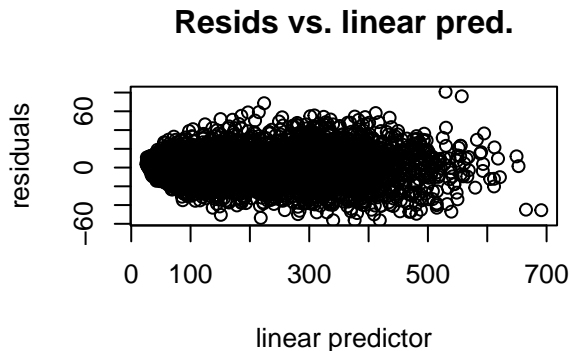
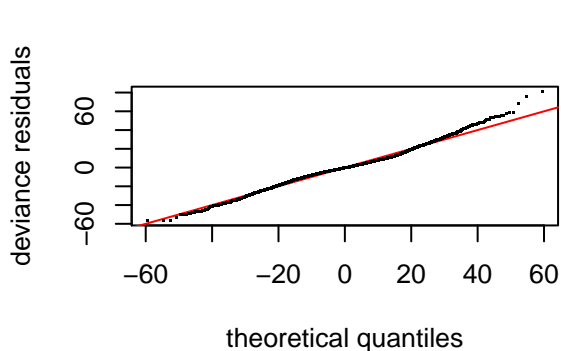


```
##  
## [[3]]
```

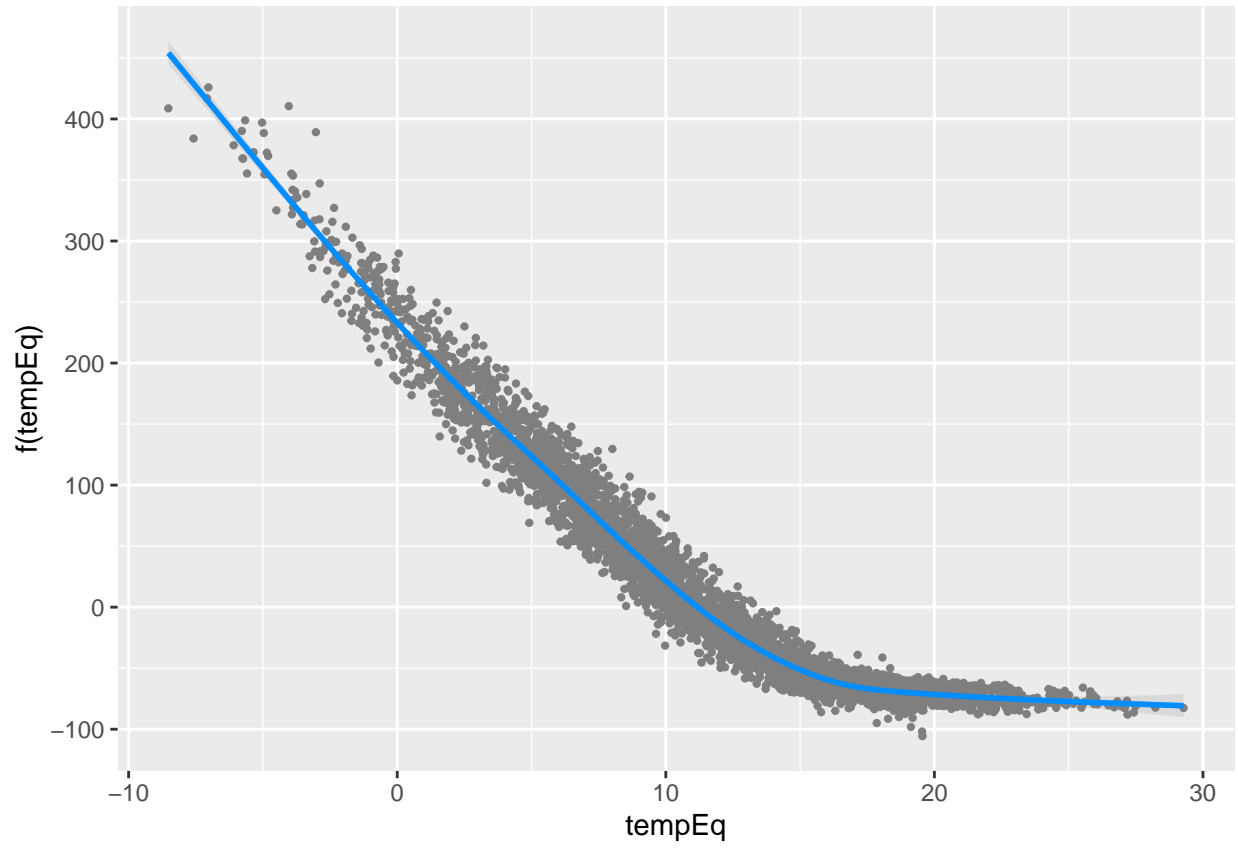


Gam check not relevant for “trend”: we want a smooth curve not depending of the fracOfYear Pattern  
 ###Test with higher k for fracOfYear

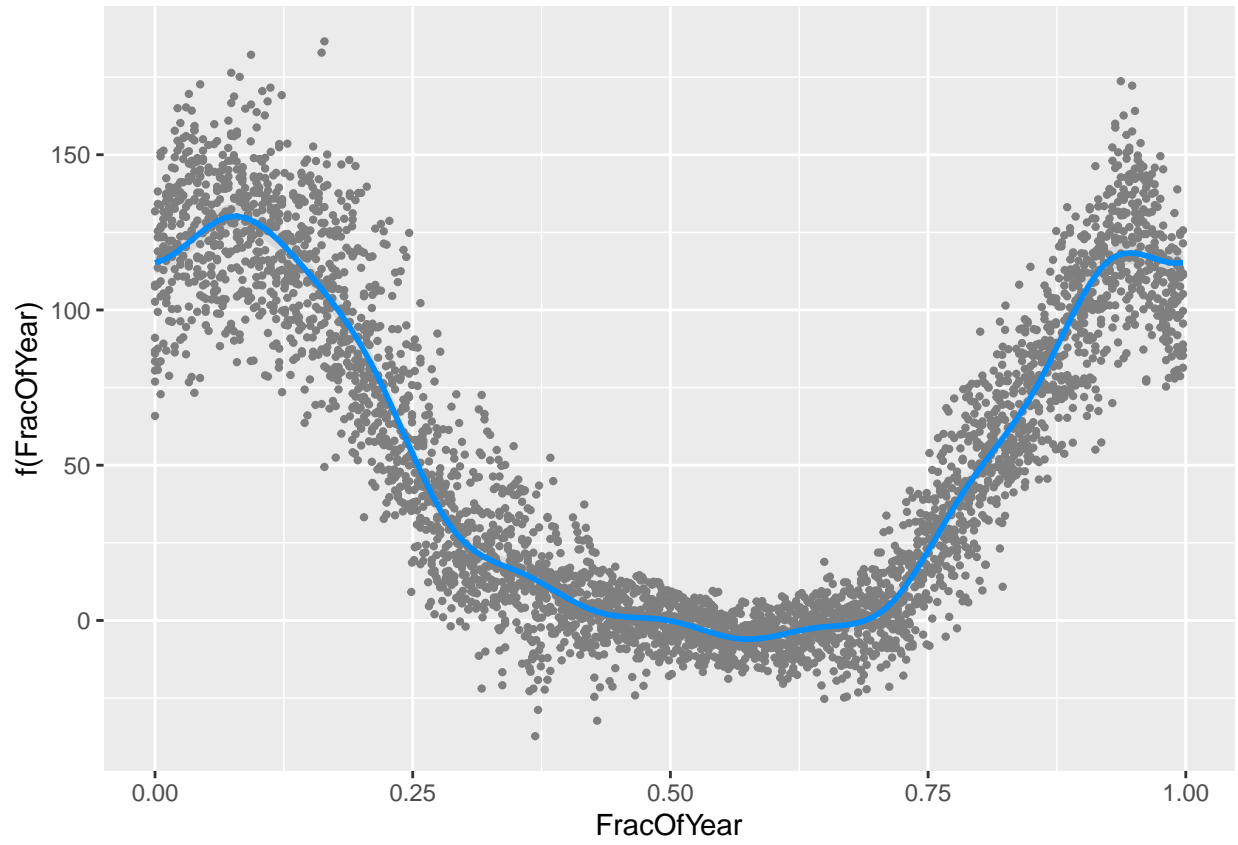
```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## GWhGaz ~ s(tempEq, bs = "cr") + s(FracOfYear, bs = "cc", k = 15) +
##       s(trend, bs = "cr", k = 7)
##
## Parametric coefficients:
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept) 190.1338    0.2561   742.3  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##           edf Ref.df      F p-value
## s(tempEq)   8.306  8.832 4706.81 <2e-16 ***
## s(FracOfYear) 12.698 13.000  673.66 <2e-16 ***
## s(trend)    5.661  5.952   43.79 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) = 0.987  Deviance explained = 98.7%
## -REML = 16956  Scale est. = 263.58    n = 4018
```



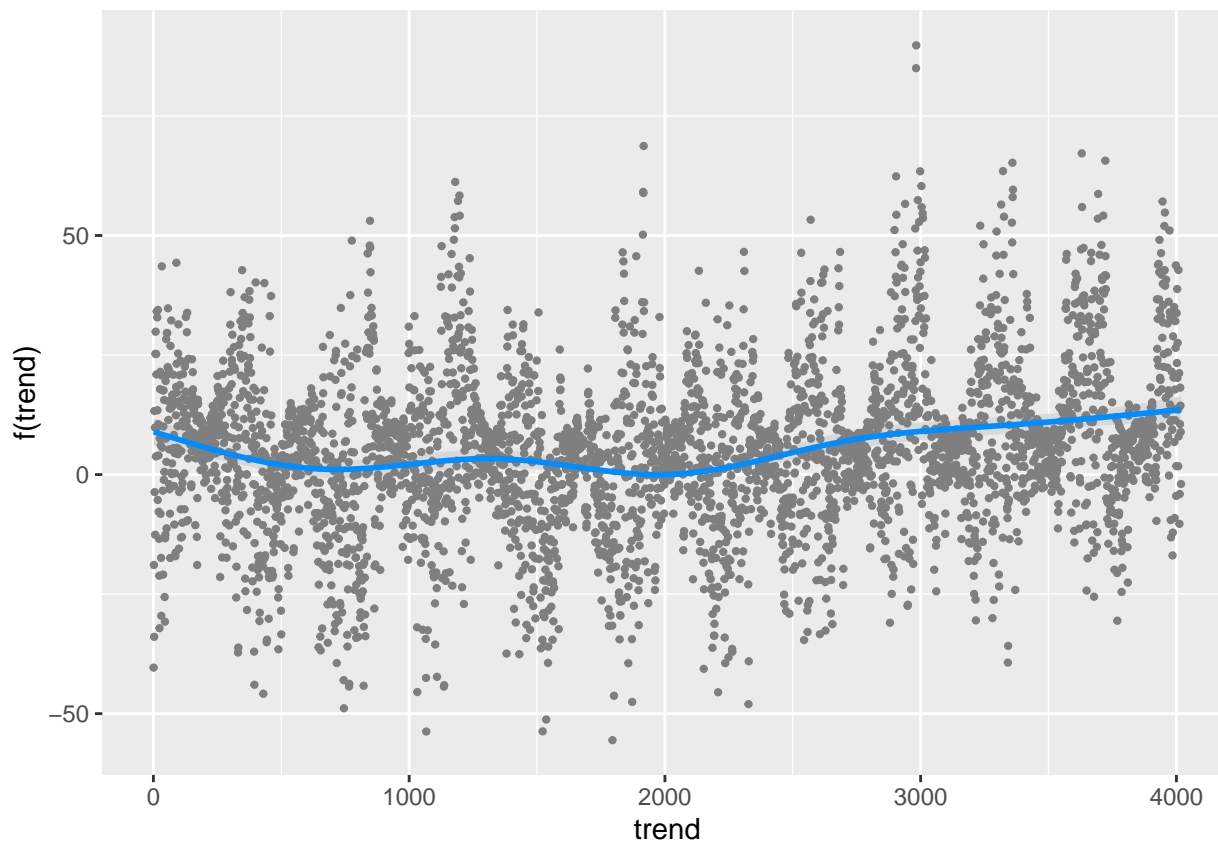
```
##
## Method: REML   Optimizer: outer newton
## full convergence after 4 iterations.
## Gradient range [-0.007315209,0.0006086586]
## (score 16956.46 & scale 263.5811).
## Hessian positive definite, eigenvalue range [1.697471,2007.537].
## Model rank = 29 / 29
##
## Basis dimension (k) checking results. Low p-value (k-index<1) may
## indicate that k is too low, especially if edf is close to k'.
##
##          k'   edf k-index p-value
## s(tempEq)   9.00  8.31   1.02   0.93
## s(FracOfYear) 13.00 12.70   1.03   0.97
## s(trend)     6.00  5.66   0.38 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## [[1]]
```



```
##  
## [[2]]
```



```
##  
## [[3]]
```

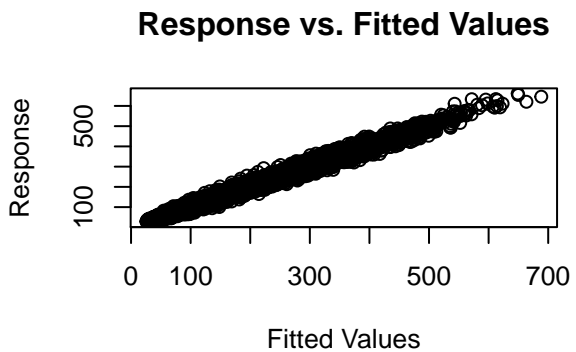
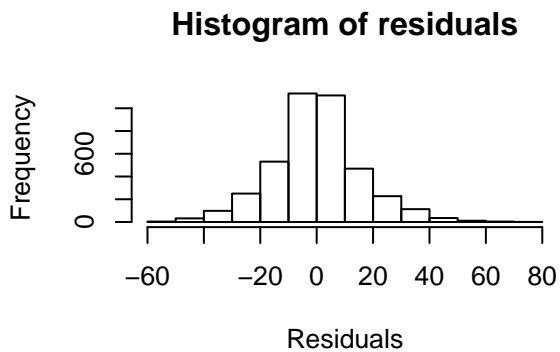
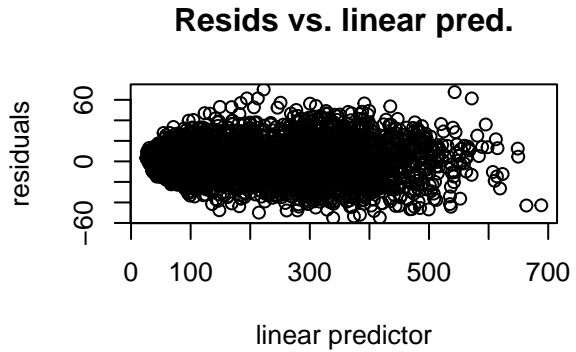
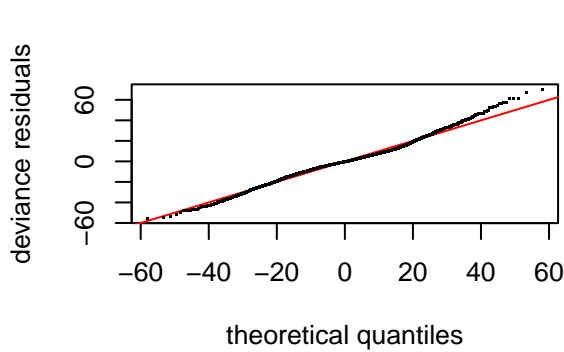


## Interactions

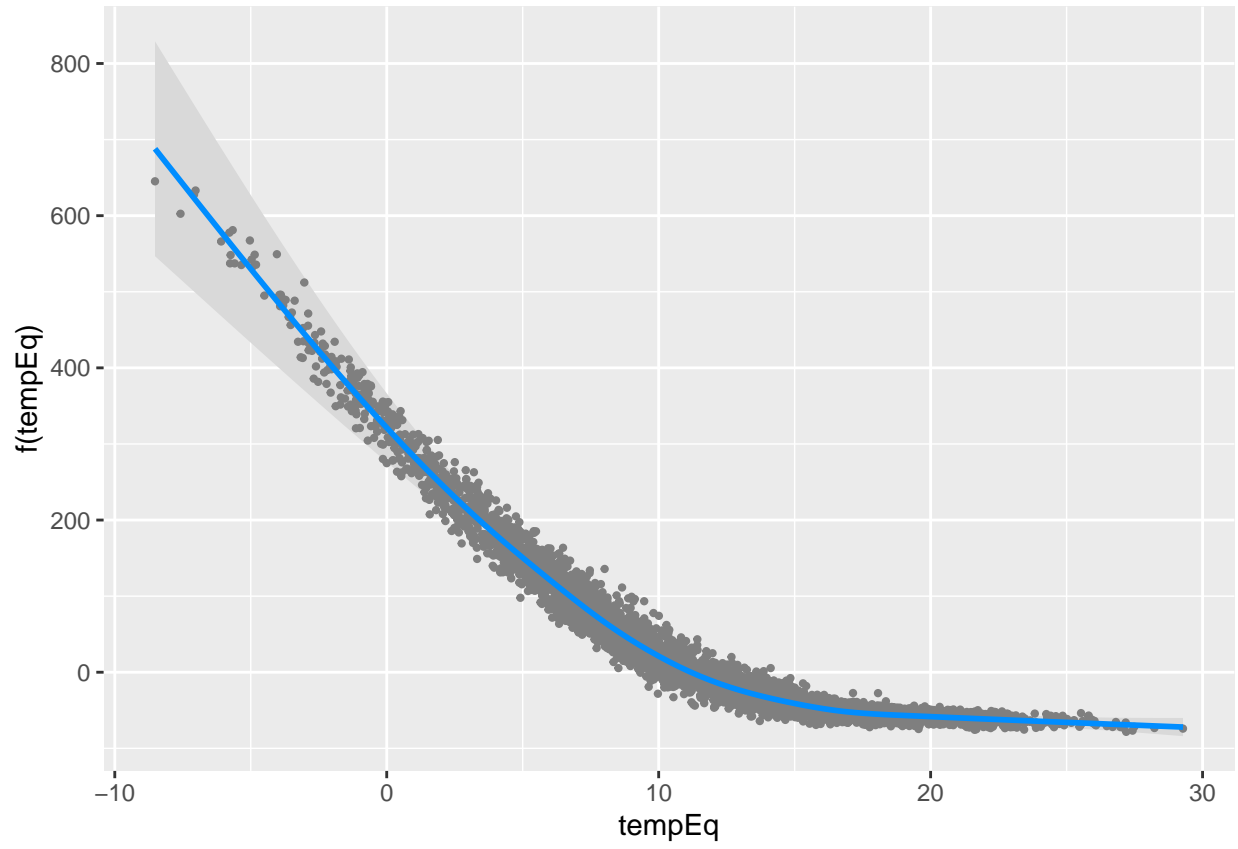
### Add (tempEq,FracOfYear)

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## GWhGaz ~ s(tempEq, bs = "cr") + s(FracOfYear, bs = "cc", k = 15) +
##       s(trend, bs = "cr", k = 7) + ti(tempEq, FracOfYear, bs = c("cr",
##       "cc"))
##
## Parametric coefficients:
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept) 182.773      2.066   88.45  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##           edf Ref.df    F p-value
## s(tempEq)      8.033  8.689 410.04 <2e-16 ***
## s(FracOfYear) 12.676 13.000 148.30 <2e-16 ***
## s(trend)       5.643  5.947  45.52 <2e-16 ***
## ti(tempEq,FracOfYear) 10.025 12.000 16.99 <2e-16 ***
```

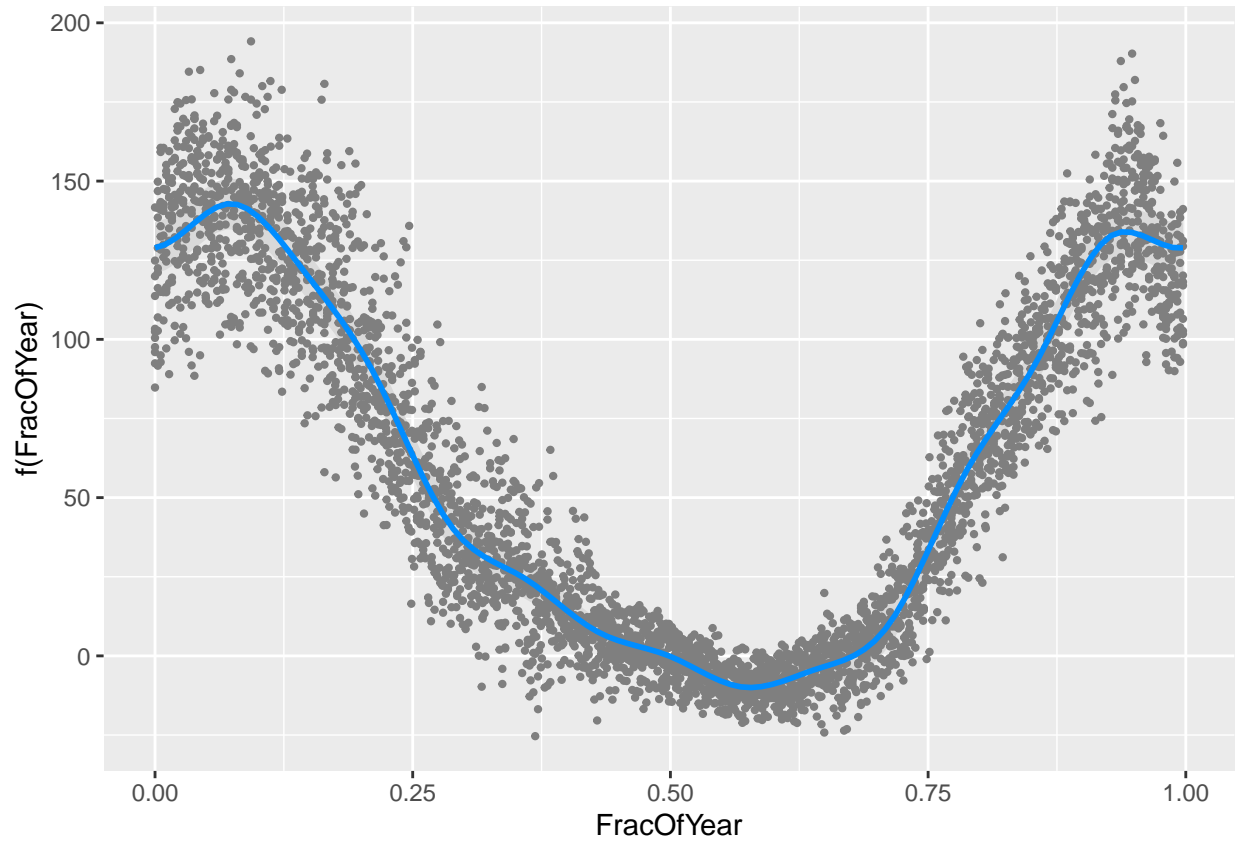
```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =  0.988   Deviance explained = 98.8%
## -REML = 16876   Scale est. = 250.8       n = 4018
```



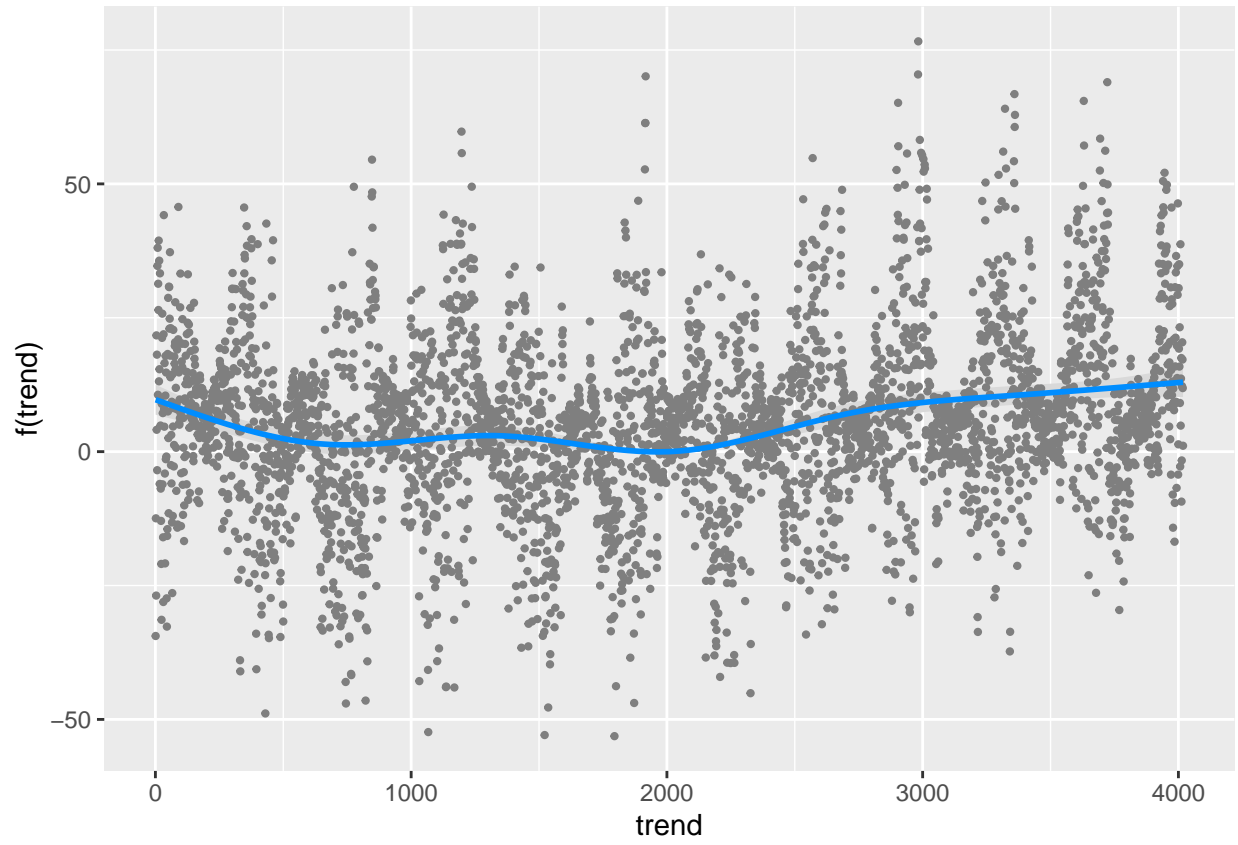
```
##
## Method: REML   Optimizer: outer newton
## full convergence after 6 iterations.
## Gradient range [-1.044704e-05,4.188331e-06]
## (score 16876.27 & scale 250.7962).
## Hessian positive definite, eigenvalue range [0.6130397,2007.535].
## Model rank = 41 / 41
##
## Basis dimension (k) checking results. Low p-value (k-index<1) may
## indicate that k is too low, especially if edf is close to k'.
##
##           k'   edf k-index p-value
## s(tempEq)      9.00  8.03   1.02   0.80
## s(FracOfYear)  13.00 12.68   1.01   0.74
## s(trend)        6.00  5.64   0.40  <2e-16 ***
## ti(tempEq,FracOfYear) 12.00 10.03  0.97   0.01 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## [[1]]
```

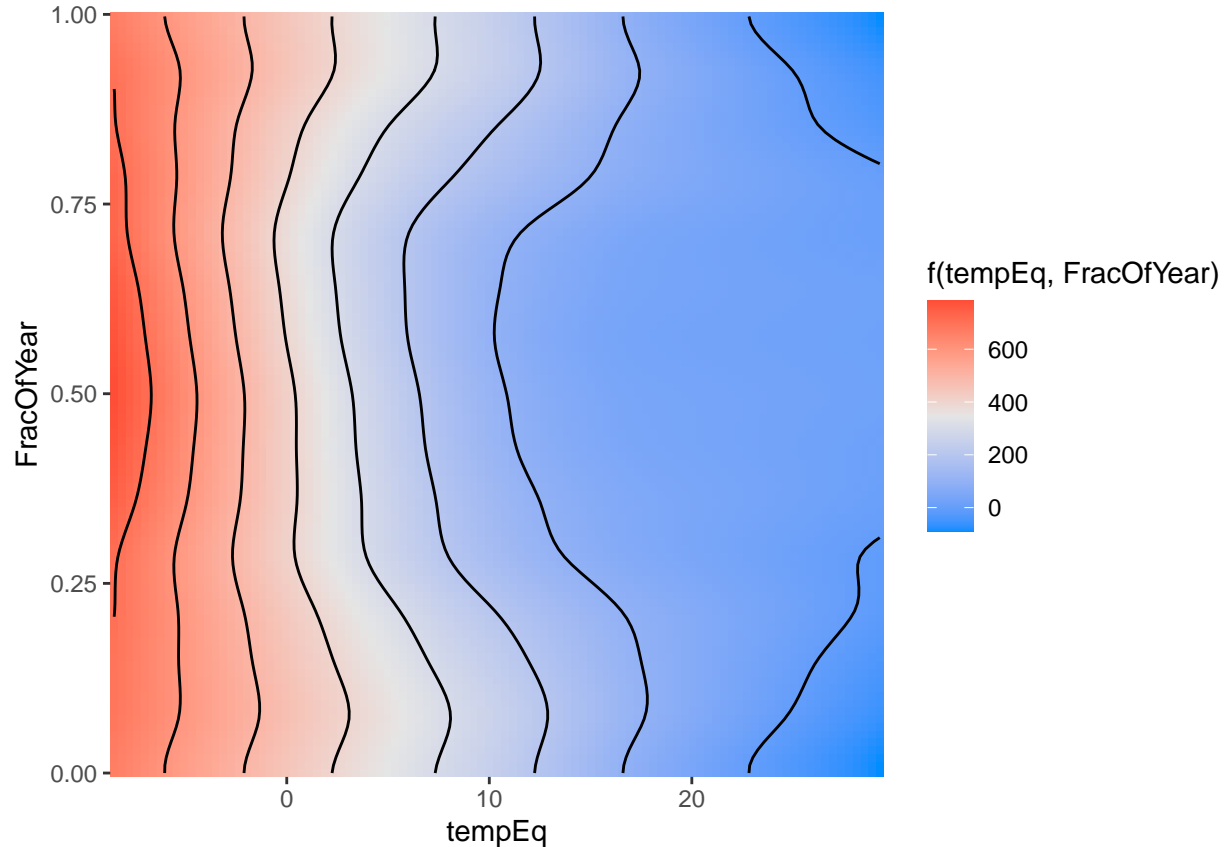


```
##  
## [[2]]
```



```
##  
## [[3]]
```

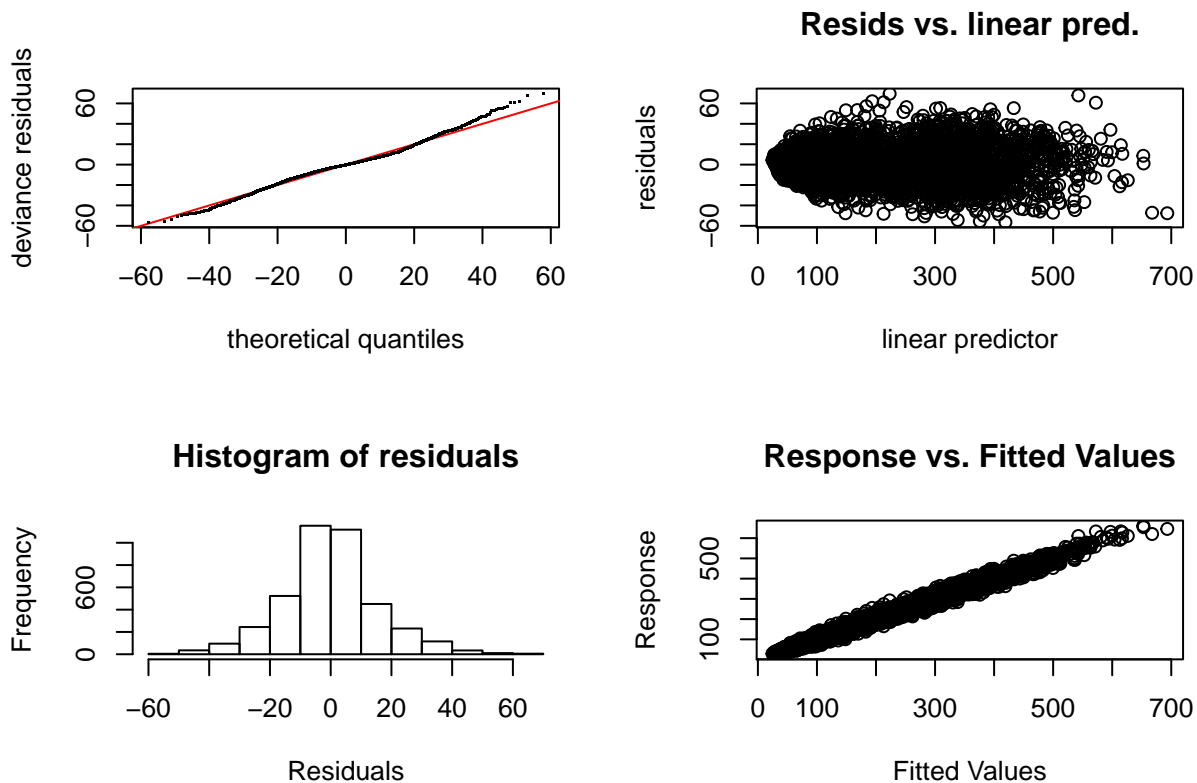




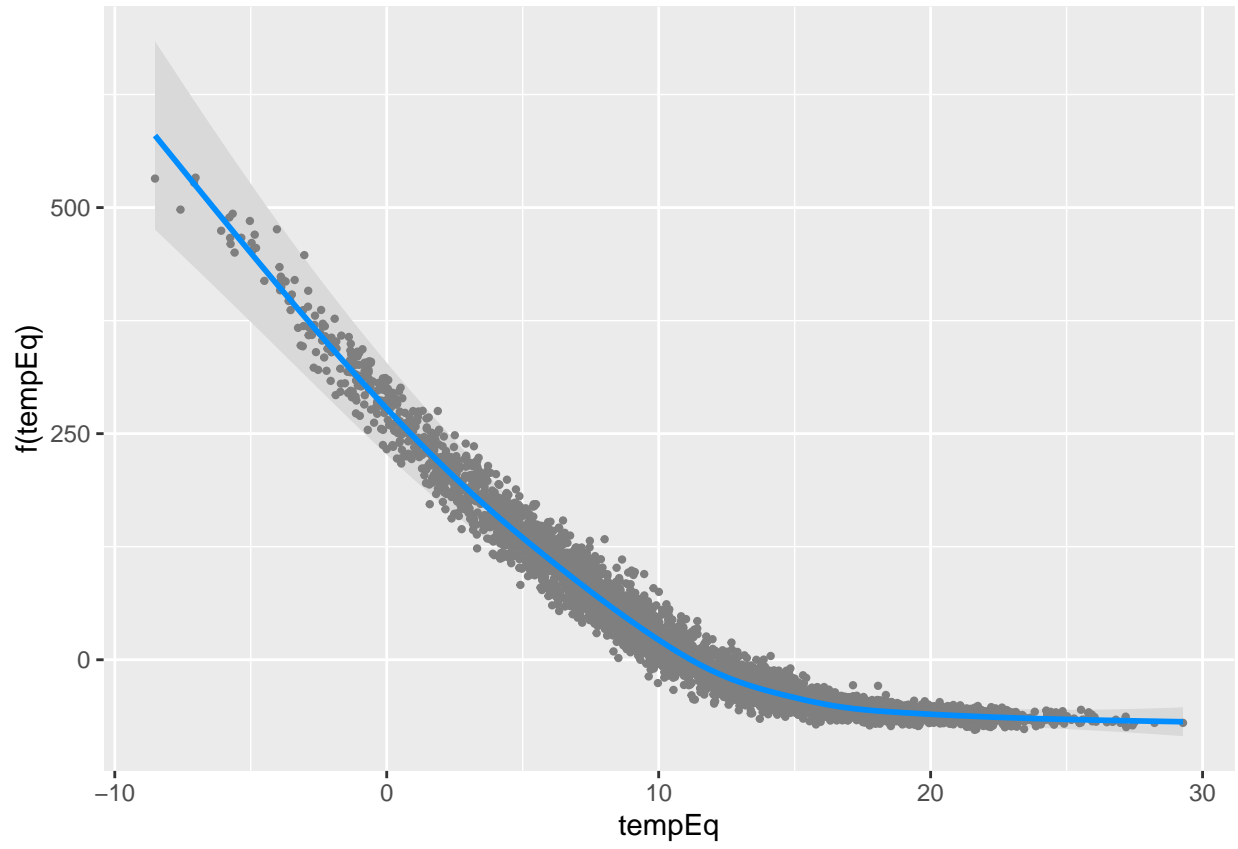
### Higher k for the interaction

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## GWhGaz ~ s(tempEq, bs = "cr") + s(FracOfYear, bs = "cc", k = 15) +
##   s(trend, bs = "cr", k = 7) + ti(tempEq, FracOfYear, bs = c("cr",
##   "cc"), k = c(7, 7))
##
## Parametric coefficients:
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept) 185.127      2.348   78.83  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##           edf Ref.df      F p-value
## s(tempEq)      7.760  8.410 174.936 <2e-16 ***
## s(FracOfYear) 12.582 13.000  67.401 <2e-16 ***
## s(trend)       5.664  5.951  44.941 <2e-16 ***
## ti(tempEq,FracOfYear) 17.283 30.000   7.846 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

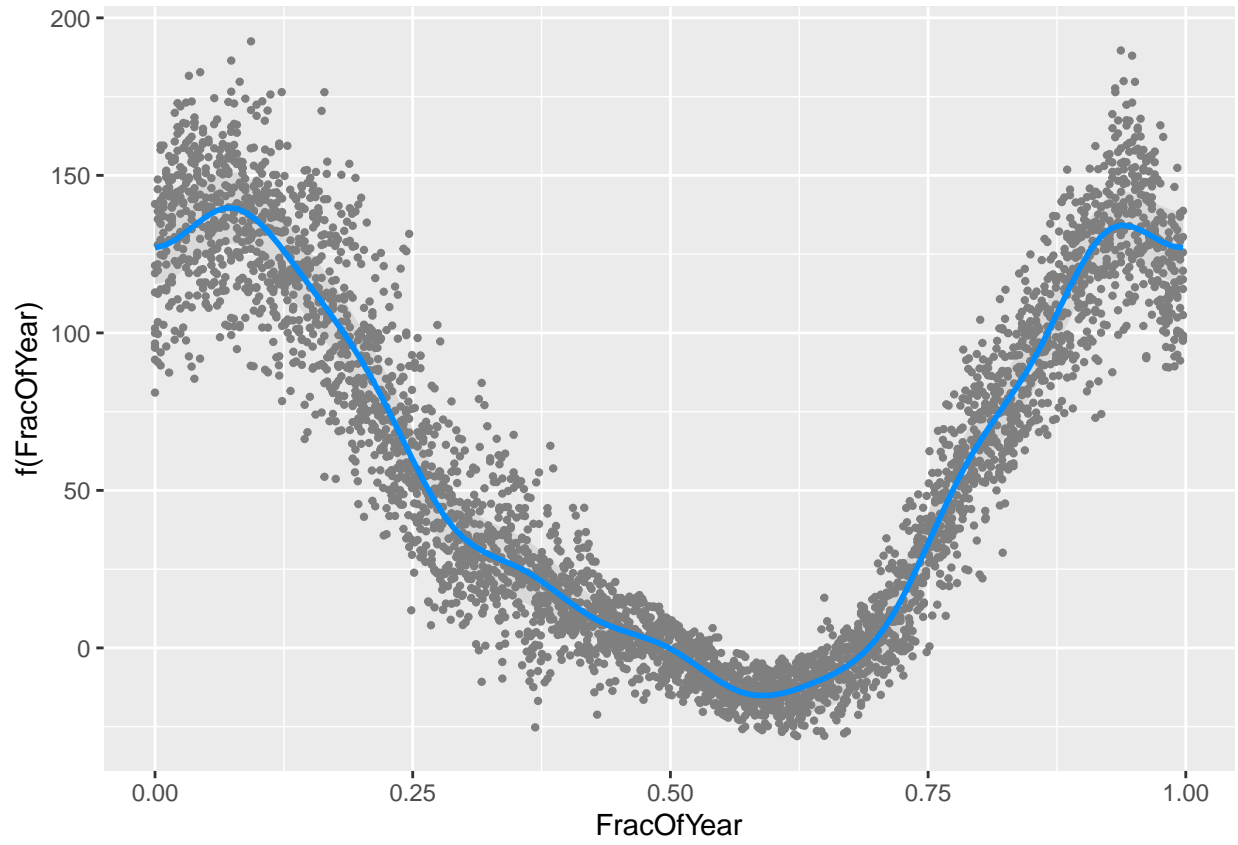
```
##
## R-sq.(adj) = 0.988   Deviance explained = 98.8%
## -REML = 16866   Scale est. = 248.92   n = 4018
```



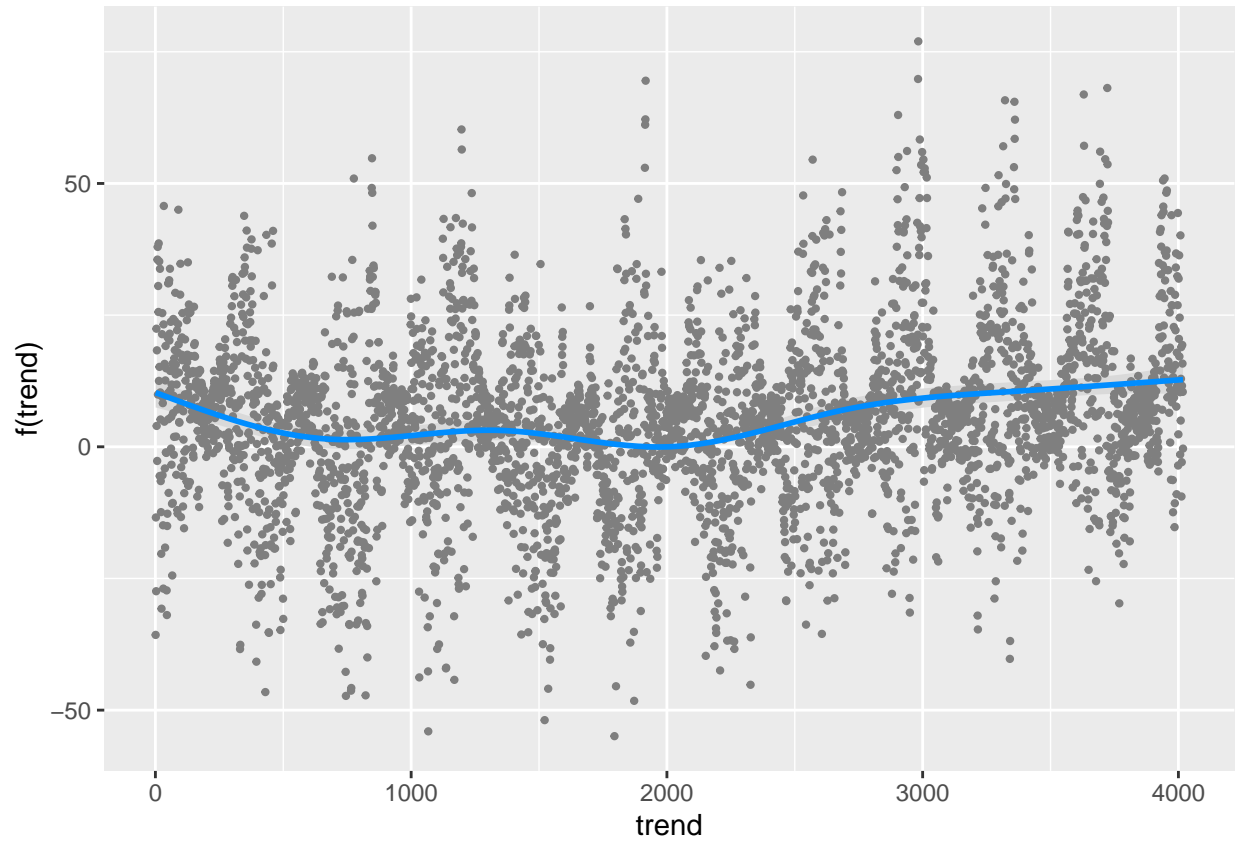
```
##
## Method: REML   Optimizer: outer newton
## full convergence after 5 iterations.
## Gradient range [-0.0002288455,9.929167e-05]
## (score 16866.39 & scale 248.9183).
## Hessian positive definite, eigenvalue range [1.047407,2007.548].
## Model rank = 59 / 59
##
## Basis dimension (k) checking results. Low p-value (k-index<1) may
## indicate that k is too low, especially if edf is close to k'.
##
##           k'   edf k-index p-value
## s(tempEq)      9.00  7.76   1.02   0.90
## s(FracOfYear)  13.00 12.58   1.01   0.78
## s(trend)        6.00  5.66   0.40  <2e-16 ***
## ti(tempEq,FracOfYear) 30.00 17.28   0.98   0.08 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## [[1]]
```

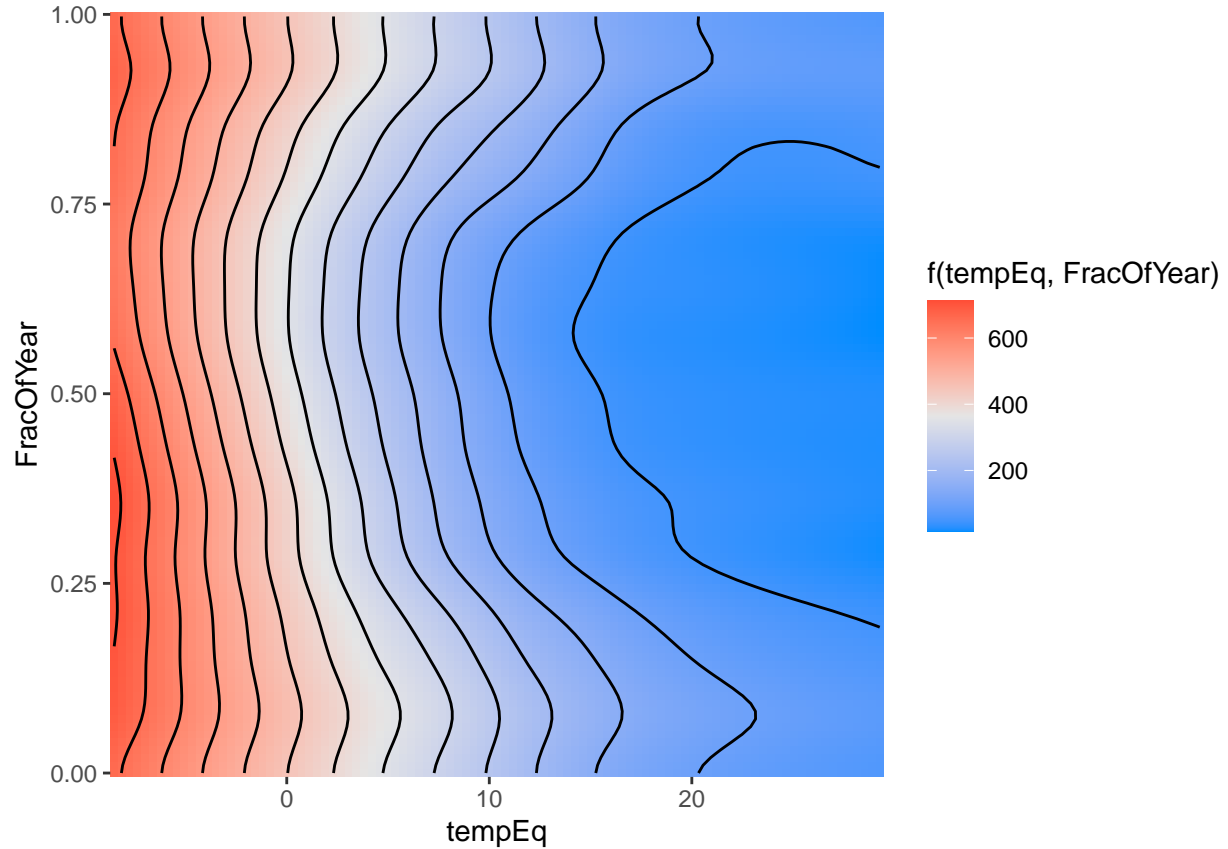


```
##  
## [[2]]
```



```
##  
## [[3]]
```



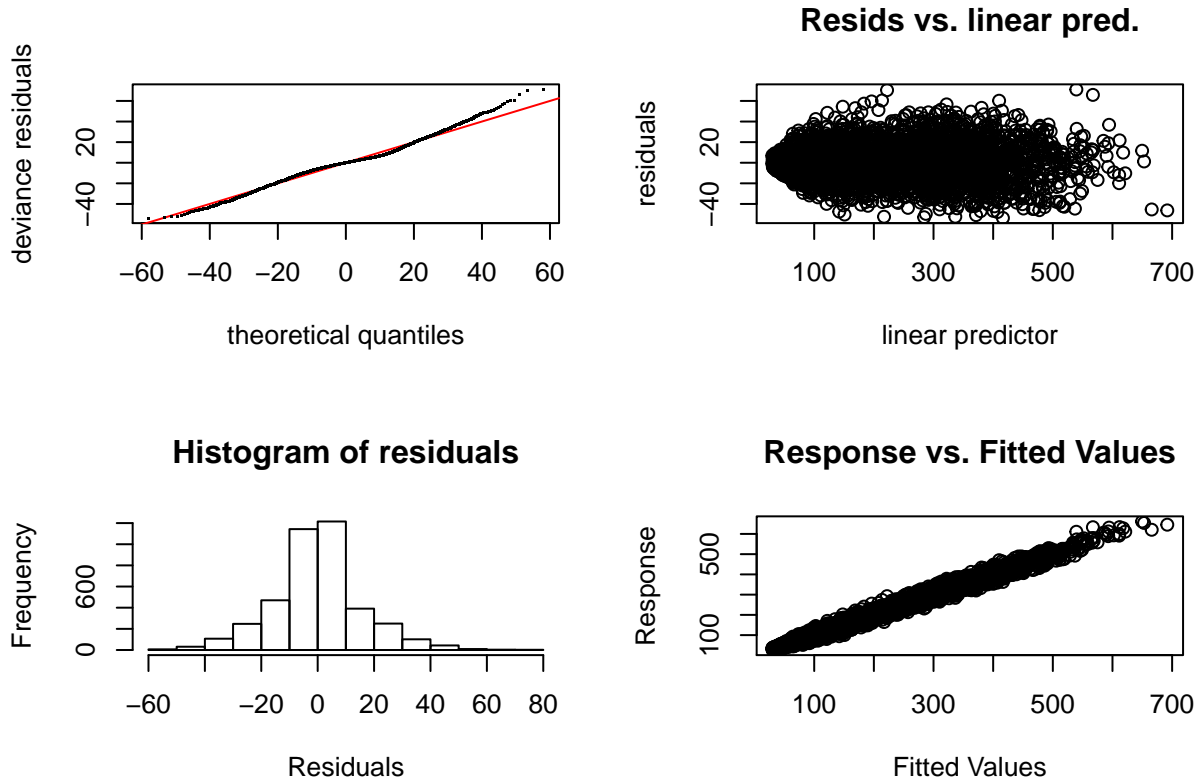


gam.check: edf =12.44 < k' =30. K large enough

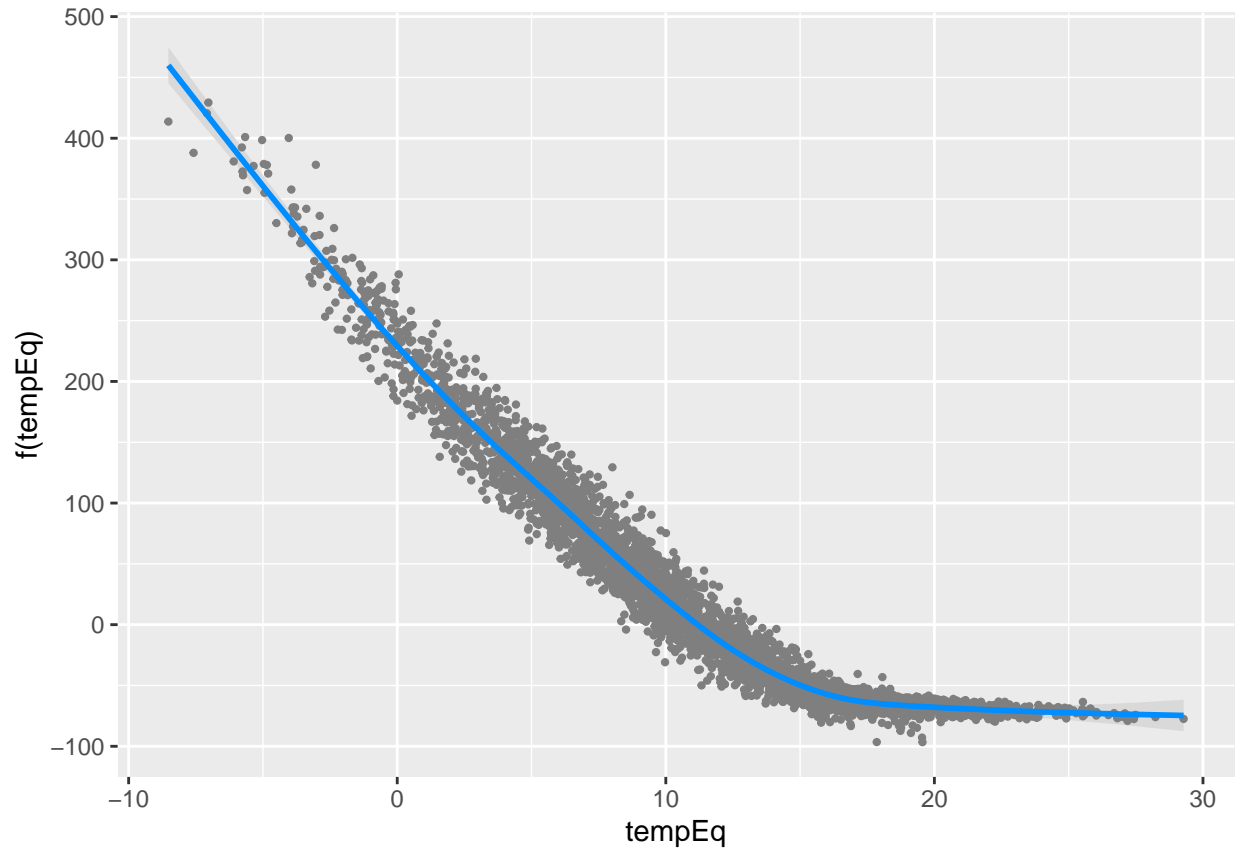
### Add (tempEq,trend)

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## GWhGaz ~ s(tempEq, bs = "cr") + s(FracOfYear, bs = "cc", k = 15) +
##       s(trend, bs = "cr", k = 7) + ti(tempEq, trend, bs = c("cr",
##       "cr"))
##
## Parametric coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept) 190.2393    0.2559   743.4   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##               edf Ref.df      F p-value
## s(tempEq)      8.348  8.852 4249.04 <2e-16 ***
## s(FracOfYear) 12.709 13.000  696.53 <2e-16 ***
## s(trend)       5.711  5.964   44.63 <2e-16 ***
## ti(tempEq,trend) 10.985 12.686   15.80 <2e-16 ***
```

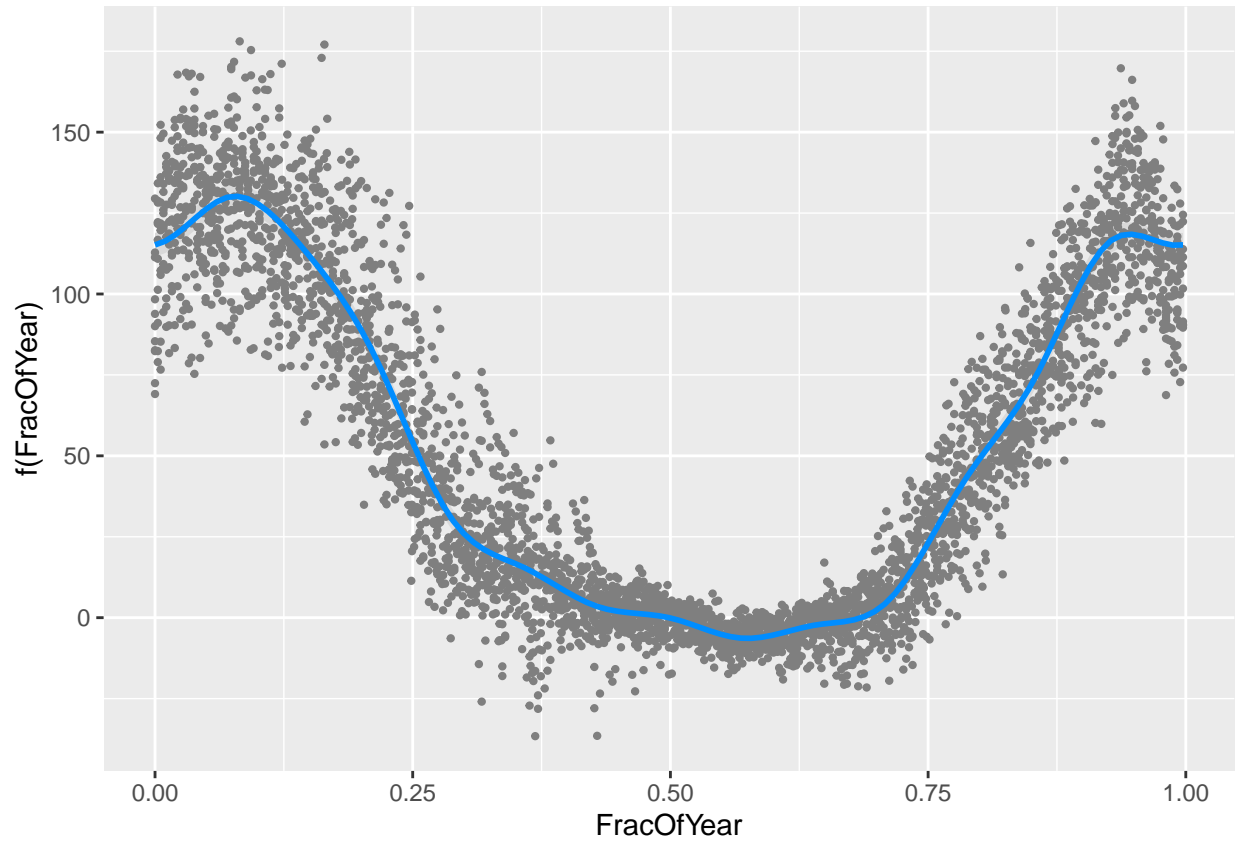
```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) = 0.988   Deviance explained = 98.8%
## -REML = 16870   Scale est. = 250.91   n = 4018
```



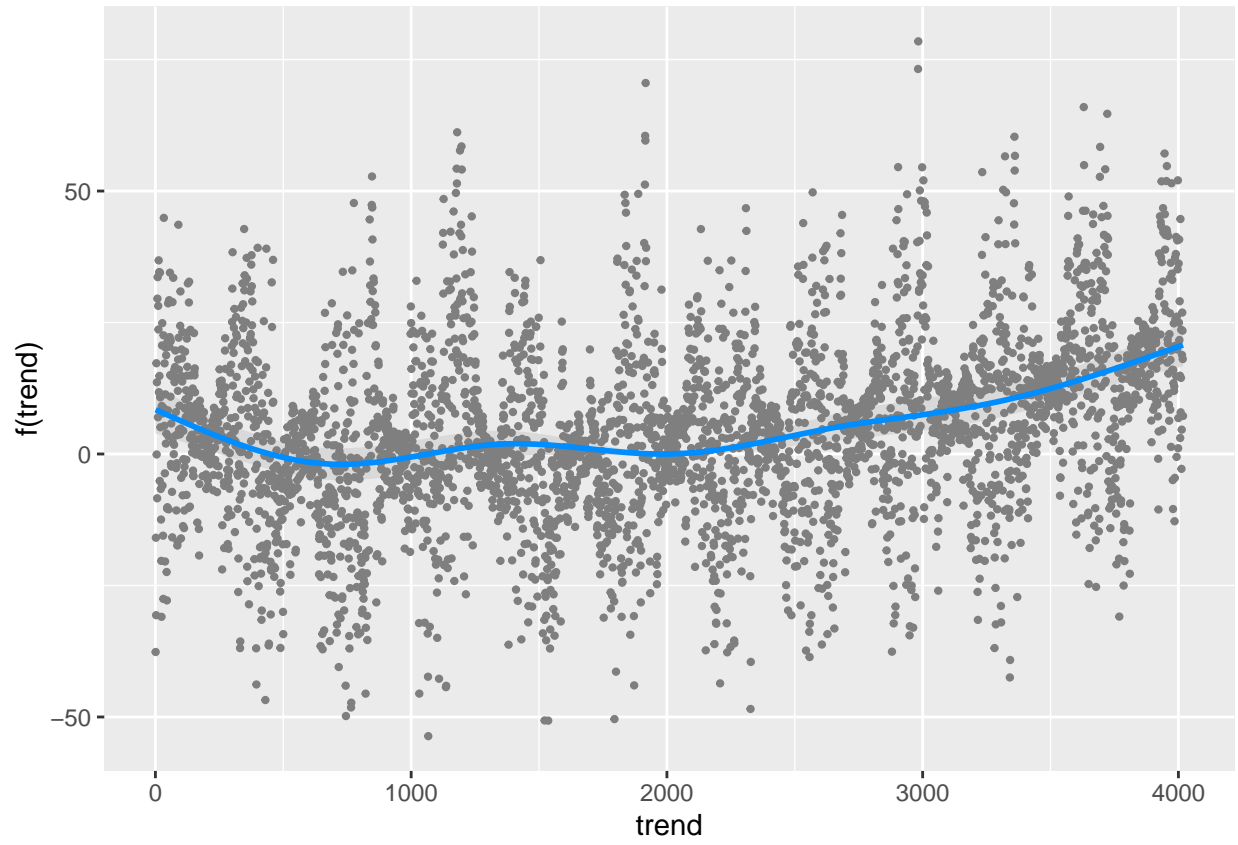
```
##
## Method: REML   Optimizer: outer newton
## full convergence after 5 iterations.
## Gradient range [-0.007495091,0.0006358759]
## (score 16869.82 & scale 250.9083).
## Hessian positive definite, eigenvalue range [1.162856,2007.043].
## Model rank = 45 / 45
##
## Basis dimension (k) checking results. Low p-value (k-index<1) may
## indicate that k is too low, especially if edf is close to k'.
##
##           k'   edf k-index p-value
## s(tempEq)    9.00  8.35   1.01   0.81
## s(FracOfYear) 13.00 12.71   1.05   1.00
## s(trend)     6.00  5.71   0.40  <2e-16 ***
## ti(tempEq,trend) 16.00 10.99   1.01   0.73
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## [[1]]
```

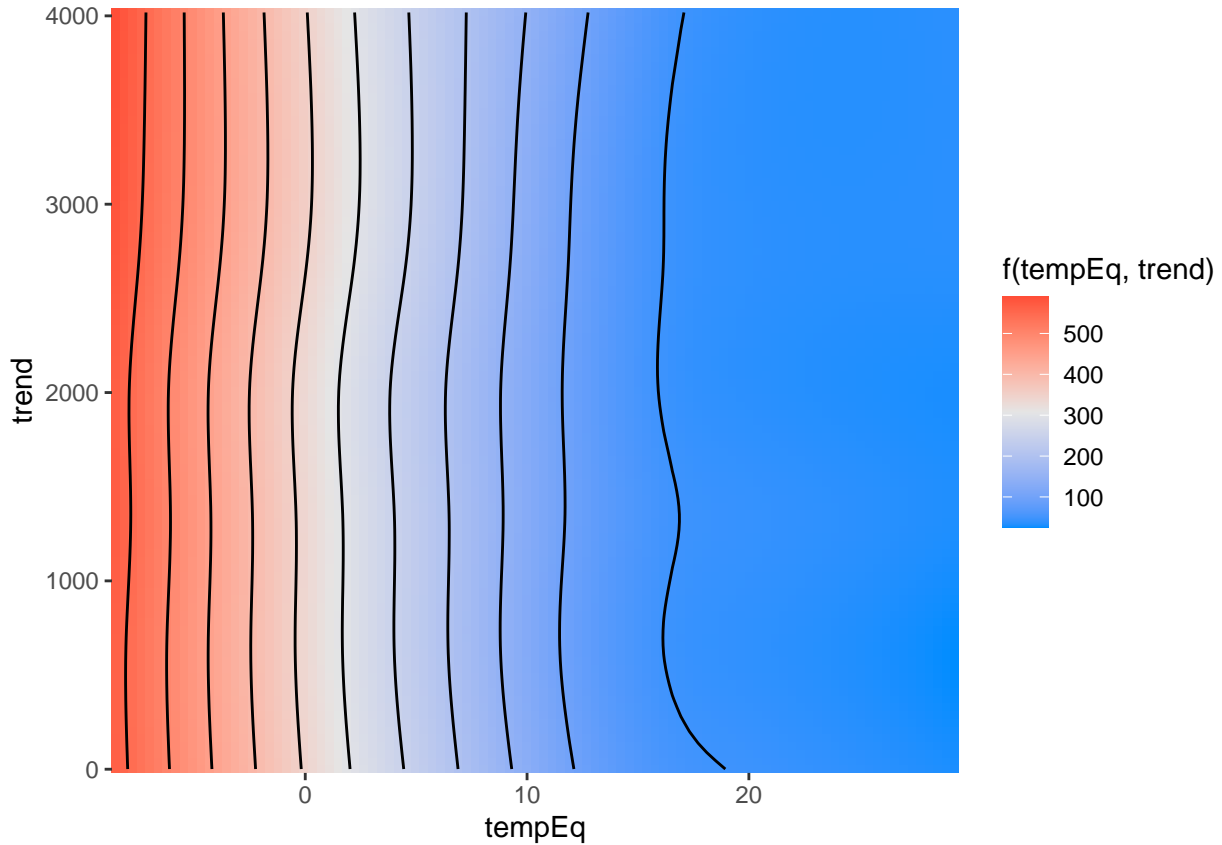


```
##  
## [[2]]
```



```
##  
## [[3]]
```

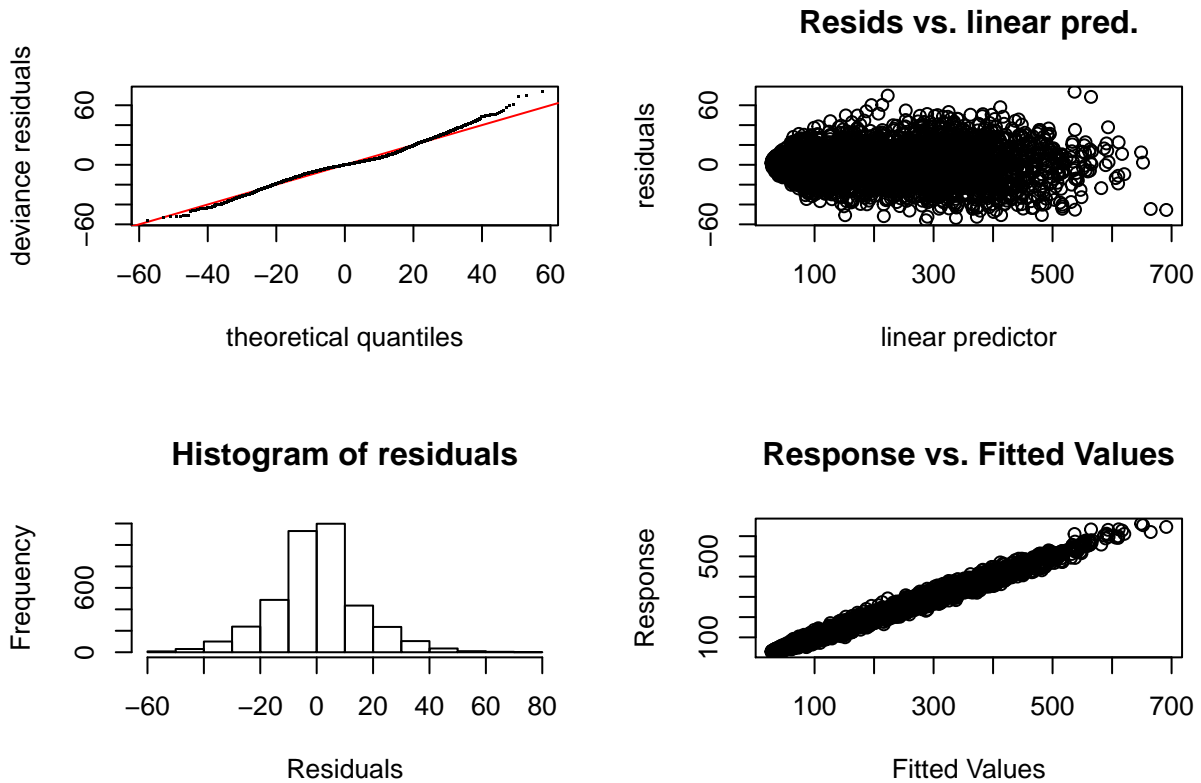




Add (trend,FracOfYear)

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## GWhGaz ~ s(tempEq, bs = "cr") + s(FracOfYear, bs = "cc", k = 15) +
##   s(trend, bs = "cr", k = 7) + ti(trend, FracOfYear, bs = c("cr",
##   "cc"))
##
## Parametric coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 190.0793    0.2497   761.2   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##             edf Ref.df      F p-value
## s(tempEq)      8.351  8.852 4784.08 <2e-16 ***
## s(FracOfYear)  12.714 13.000  715.85 <2e-16 ***
## s(trend)        5.699  5.961   41.80 <2e-16 ***
## ti(trend,FracOfYear) 10.016 12.000   22.19 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
## R-sq.(adj) = 0.988   Deviance explained = 98.8%
## -REML = 16842   Scale est. = 247.05   n = 4018
```



```
##
## Method: REML   Optimizer: outer newton
## full convergence after 6 iterations.
## Gradient range [-0.0145085,0.007359684]
## (score 16842.16 & scale 247.052).
## Hessian positive definite, eigenvalue range [0.2125765,2007.554].
## Model rank = 41 / 41
##
## Basis dimension (k) checking results. Low p-value (k-index<1) may
## indicate that k is too low, especially if edf is close to k'.
##
##           k'   edf k-index p-value
## s(tempEq)      9.00  8.35   1.01   0.84
## s(FracOfYear)  13.00 12.71   1.04   0.99
## s(trend)        6.00  5.70   0.41  <2e-16 ***
## ti(trend,FracOfYear) 12.00 10.02   1.06   1.00
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

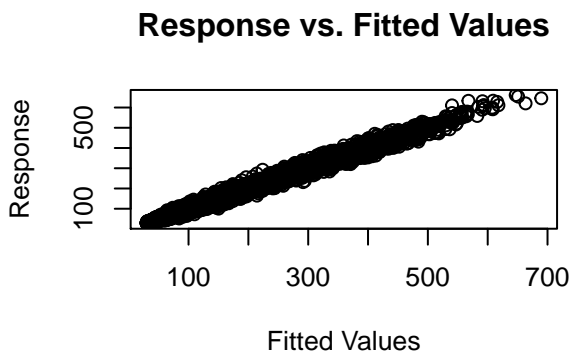
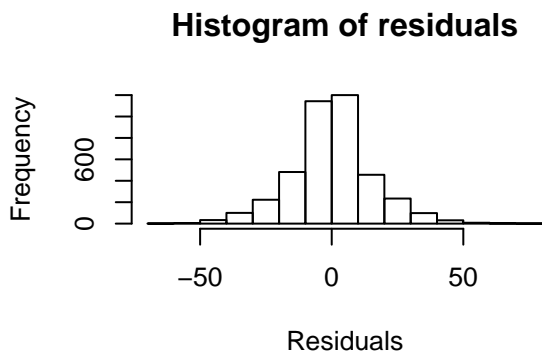
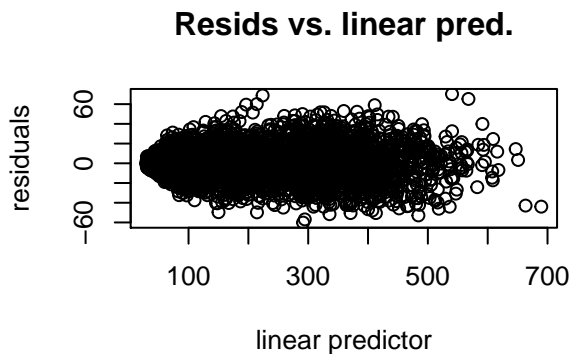
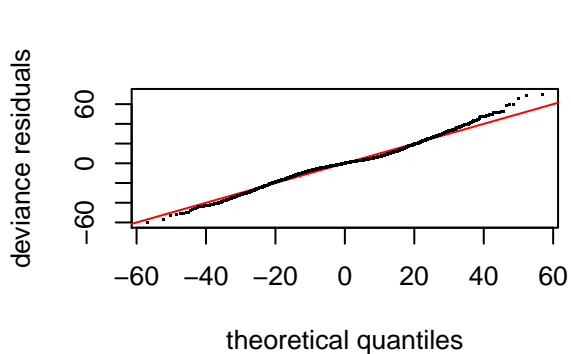
Higher k

```
##
```

```

## Family: gaussian
## Link function: identity
##
## Formula:
## GWhGaz ~ s(tempEq, bs = "cr") + s(FracOfYear, bs = "cc", k = 15) +
##       s(trend, bs = "cr", k = 7) + ti(trend, FracOfYear, bs = c("cr",
##       "cc"), k = c(7, 12))
##
## Parametric coefficients:
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept) 190.1038    0.2486   764.7  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##           edf Ref.df      F p-value
## s(tempEq)    8.362  8.854 4736.012 <2e-16 ***
## s(FracOfYear) 12.726 13.000  720.839 <2e-16 ***
## s(trend)     5.688  5.954  42.217 <2e-16 ***
## ti(trend,FracOfYear) 36.980 60.000   6.236 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) = 0.988  Deviance explained = 98.8%
## -REML = 16822  Scale est. = 240.93    n = 4018

```

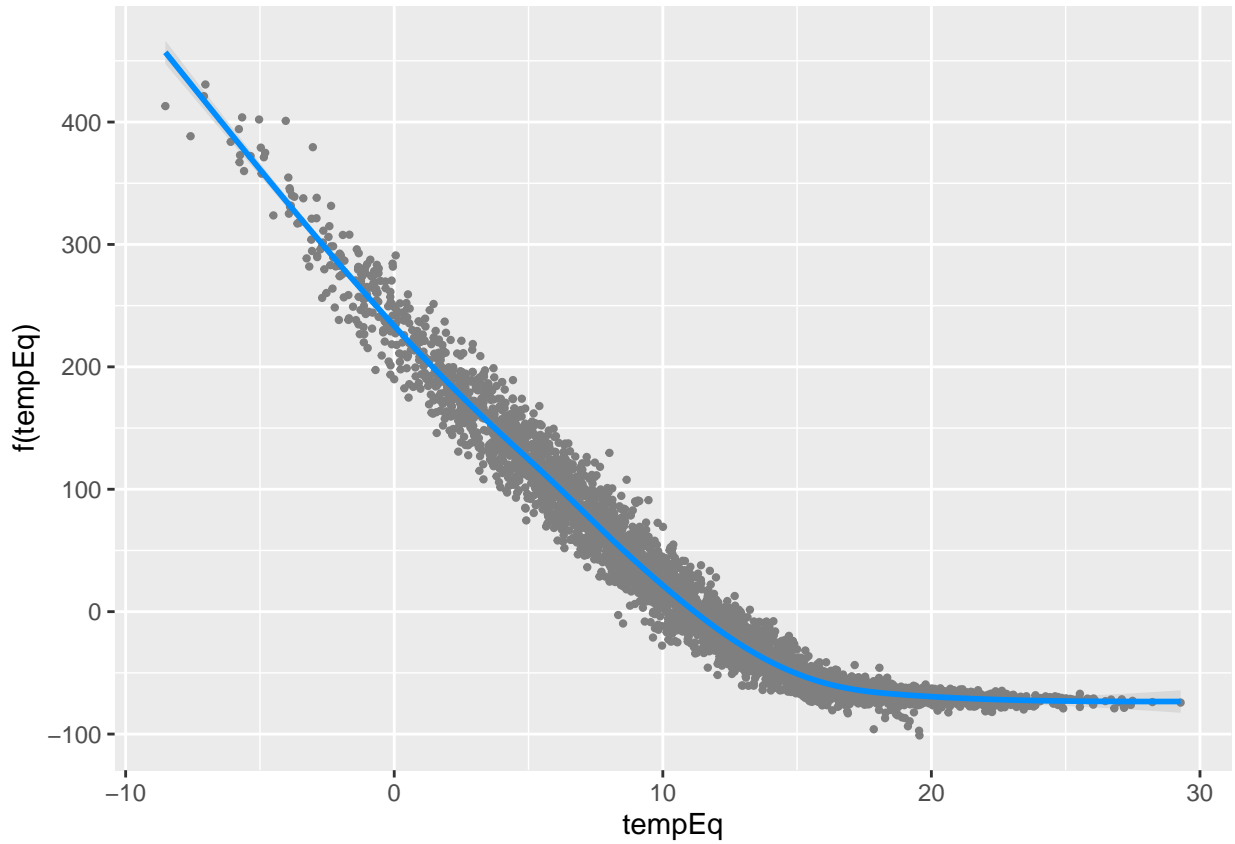


```
##
```

```

## Method: REML   Optimizer: outer newton
## full convergence after 4 iterations.
## Gradient range [-0.0001662709,0.0001333639]
## (score 16822.45 & scale 240.9299).
## Hessian positive definite, eigenvalue range [1.837549,2007.616].
## Model rank = 89 / 89
##
## Basis dimension (k) checking results. Low p-value (k-index<1) may
## indicate that k is too low, especially if edf is close to k'.
##
##           k'   edf k-index p-value
## s(tempEq)      9.00  8.36   1.02   0.88
## s(FracOfYear) 13.00 12.73   1.04   0.98
## s(trend)       6.00  5.69   0.42 <2e-16 ***
## ti(trend,FracOfYear) 60.00 36.98   1.06   1.00
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## [[1]]

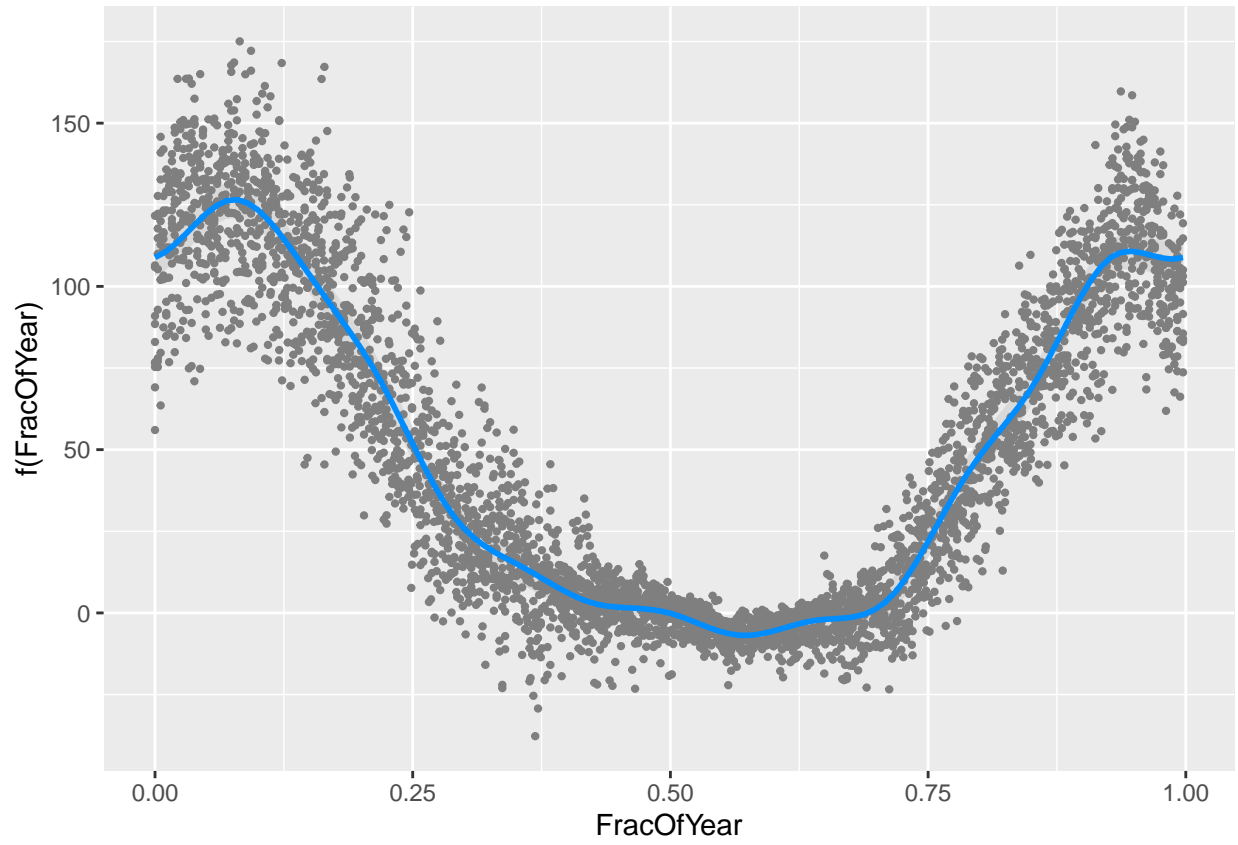
```



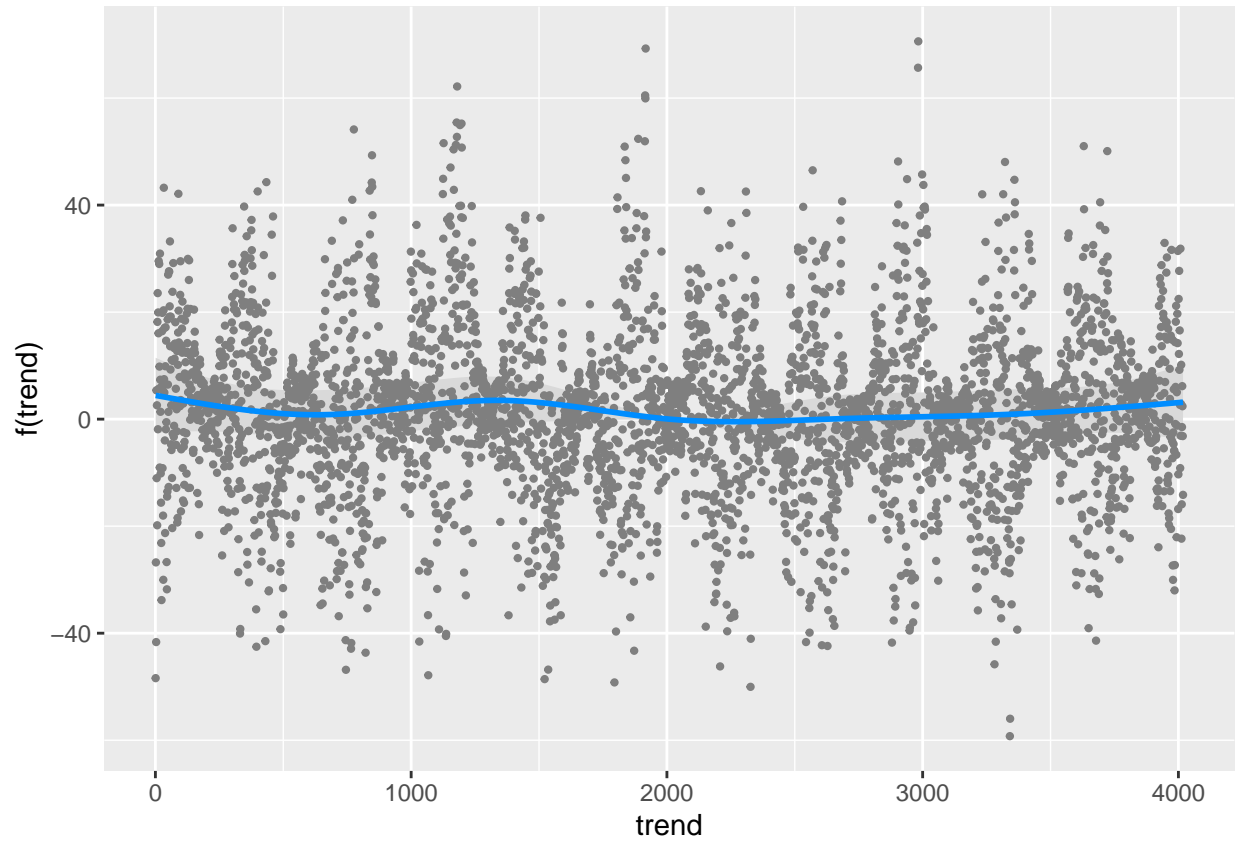
```

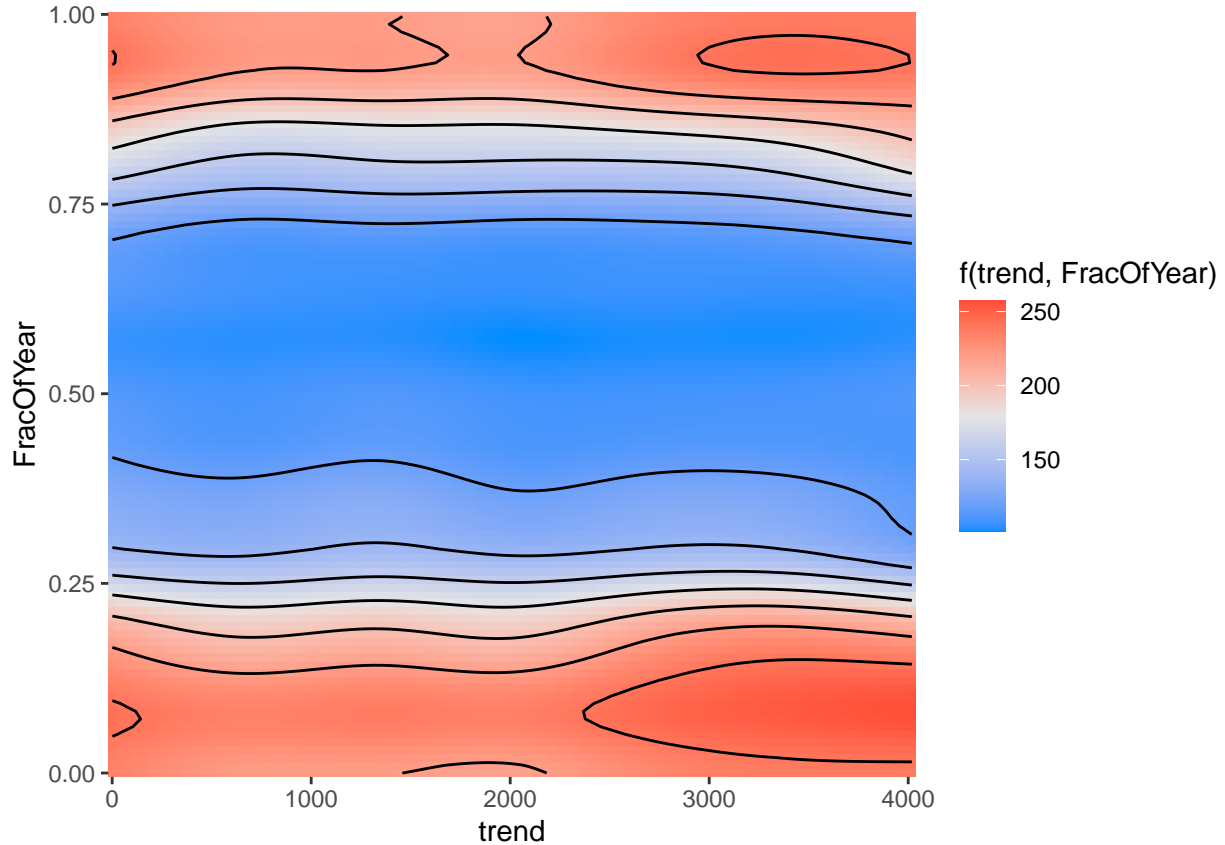
##
## [[2]]

```



```
##  
## [[3]]
```

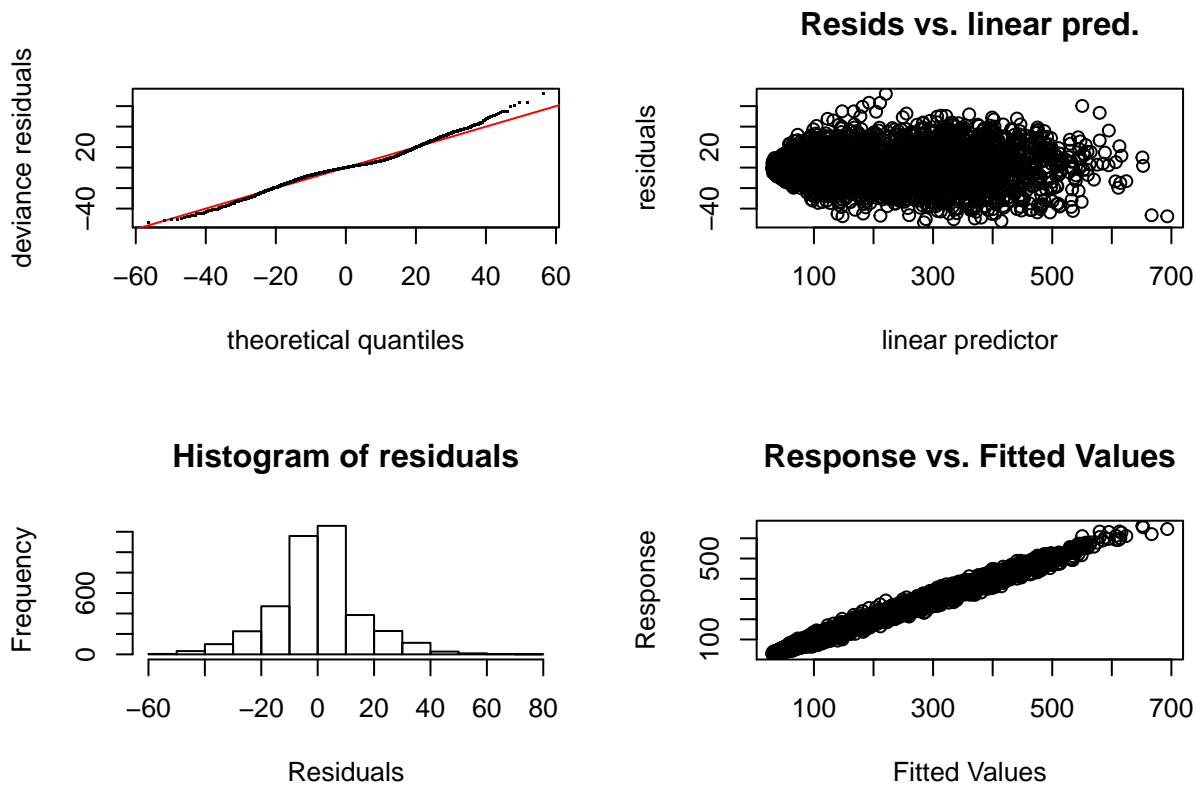




gam.check: edf =12.44 < k' =30. K large enough ###Combination of interactions

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## GWhGaz ~ s(tempEq, bs = "cr") + s(FracOfYear, bs = "cc", k = 15) +
##       s(trend, bs = "cr", k = 7) + ti(tempEq, FracOfYear, bs = c("cr",
##       "cc"), k = c(7, 7)) + ti(tempEq, trend, bs = c("cr", "cr"))
##
## Parametric coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  185.622      2.281   81.38  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##               edf Ref.df      F p-value
## s(tempEq)      7.849  8.467 188.212 <2e-16 ***
## s(FracOfYear) 12.607 13.000  70.469 <2e-16 ***
## s(trend)       5.700  5.960  45.936 <2e-16 ***
## ti(tempEq,FracOfYear) 17.255 30.000   8.115 <2e-16 ***
## ti(tempEq,trend) 10.322 12.191  16.779 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
## R-sq.(adj) = 0.988   Deviance explained = 98.8%
## -REML = 16776   Scale est. = 236.75   n = 4018
```



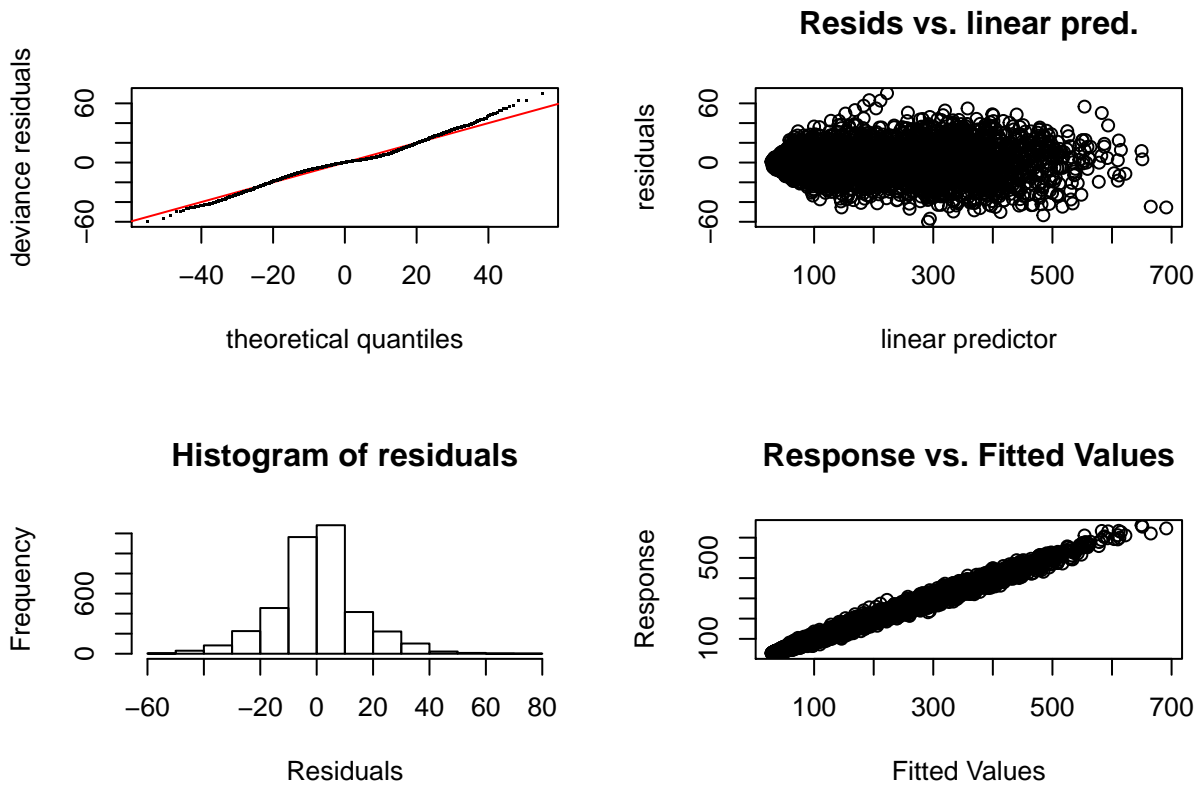
```
##
## Method: REML   Optimizer: outer newton
## full convergence after 4 iterations.
## Gradient range [-0.0004557463,0.0002872526]
## (score 16776.19 & scale 236.7499).
## Hessian positive definite, eigenvalue range [0.8430267,2007.054].
## Model rank = 75 / 75
##
## Basis dimension (k) checking results. Low p-value (k-index<1) may
## indicate that k is too low, especially if edf is close to k'.
##
##          k'   edf k-index p-value
## s(tempEq)      9.00  7.85   1.01  0.76
## s(FracOfYear) 13.00 12.61   1.03  0.98
## s(trend)       6.00  5.70   0.42 <2e-16 ***
## ti(tempEq,FracOfYear) 30.00 17.26   0.98  0.12
## ti(tempEq,trend)  16.00 10.32   1.00  0.47
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

##
## Family: gaussian
## Link function: identity
##
```

```

## Formula:
## GWhGaz ~ s(tempEq, bs = "cr") + s(FracOfYear, bs = "cc", k = 15) +
##   s(trend, bs = "cr", k = 7) + ti(tempEq, FracOfYear, bs = c("cr",
##   "cc"), k = c(7, 7)) + ti(trend, FracOfYear, bs = c("cr",
##   "cc"), k = c(7, 12))
##
## Parametric coefficients:
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept) 184.855      2.165   85.39 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##           edf Ref.df      F p-value
## s(tempEq)      7.802  8.432 202.468 <2e-16 ***
## s(FracOfYear) 12.650 13.000  78.338 <2e-16 ***
## s(trend)       5.692  5.954  44.659 <2e-16 ***
## ti(tempEq,FracOfYear) 16.852 30.000   8.784 <2e-16 ***
## ti(trend,FracOfYear) 39.184 60.000   6.910 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) = 0.989  Deviance explained = 98.9%
## -REML = 16718  Scale est. = 225.52    n = 4018

```



```

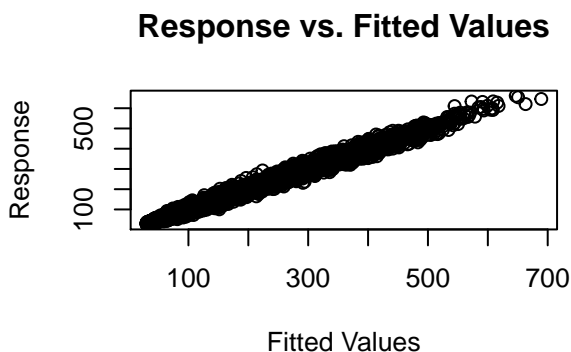
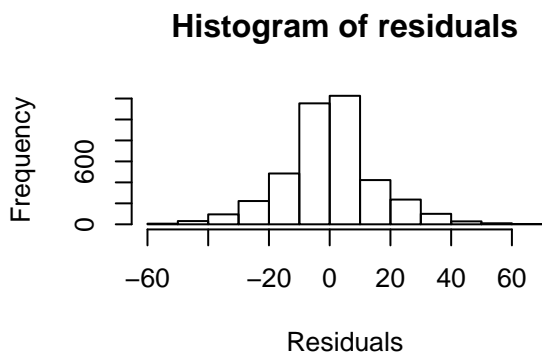
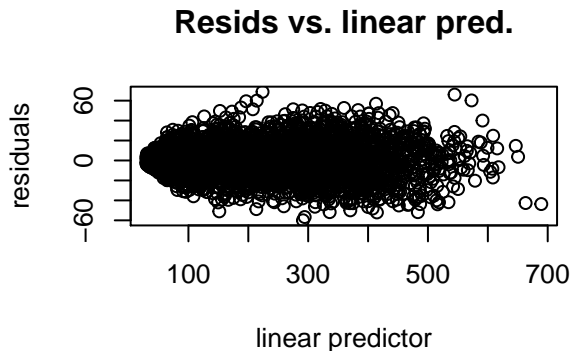
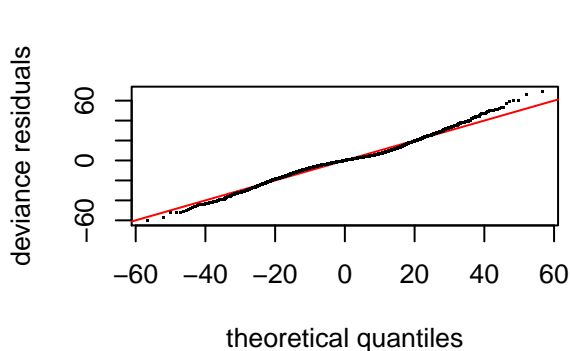
##
## Method: REML  Optimizer: outer newton

```

```

## full convergence after 4 iterations.
## Gradient range [-0.0007815956,0.0006188759]
## (score 16718.34 & scale 225.522).
## Hessian positive definite, eigenvalue range [0.9910278,2007.644].
## Model rank = 119 / 119
##
## Basis dimension (k) checking results. Low p-value (k-index<1) may
## indicate that k is too low, especially if edf is close to k'.
##
##           k'   edf k-index p-value
## s(tempEq)      9.00  7.80   1.01  0.790
## s(FracOfYear) 13.00 12.65   1.02  0.910
## s(trend)       6.00  5.69   0.44 <2e-16 ***
## ti(tempEq,FracOfYear) 30.00 16.85   0.98  0.035 *
## ti(trend,FracOfYear) 60.00 39.18   1.05  1.000
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Family: gaussian
## Link function: identity
##
## Formula:
## GWhGaz ~ s(tempEq, bs = "cr") + s(FracOfYear, bs = "cc", k = 15) +
##       s(trend, bs = "cr", k = 7) + ti(tempEq, trend, bs = c("cr",
##       "cr")) + ti(trend, FracOfYear, bs = c("cr", "cc"), k = c(7,
##       12))
##
## Parametric coefficients:
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept) 190.1778    0.2554   744.6 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##           edf Ref.df      F p-value
## s(tempEq)      8.381  8.862 4296.742 < 2e-16 ***
## s(FracOfYear) 12.728 13.000  718.480 < 2e-16 ***
## s(trend)       5.724  5.962   41.086 < 2e-16 ***
## ti(tempEq,trend) 10.022 12.082    2.884 0.00054 ***
## ti(trend,FracOfYear) 35.489 60.000    3.381 < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) = 0.988  Deviance explained = 98.8%
## -REML = 16811  Scale est. = 238.87    n = 4018

```

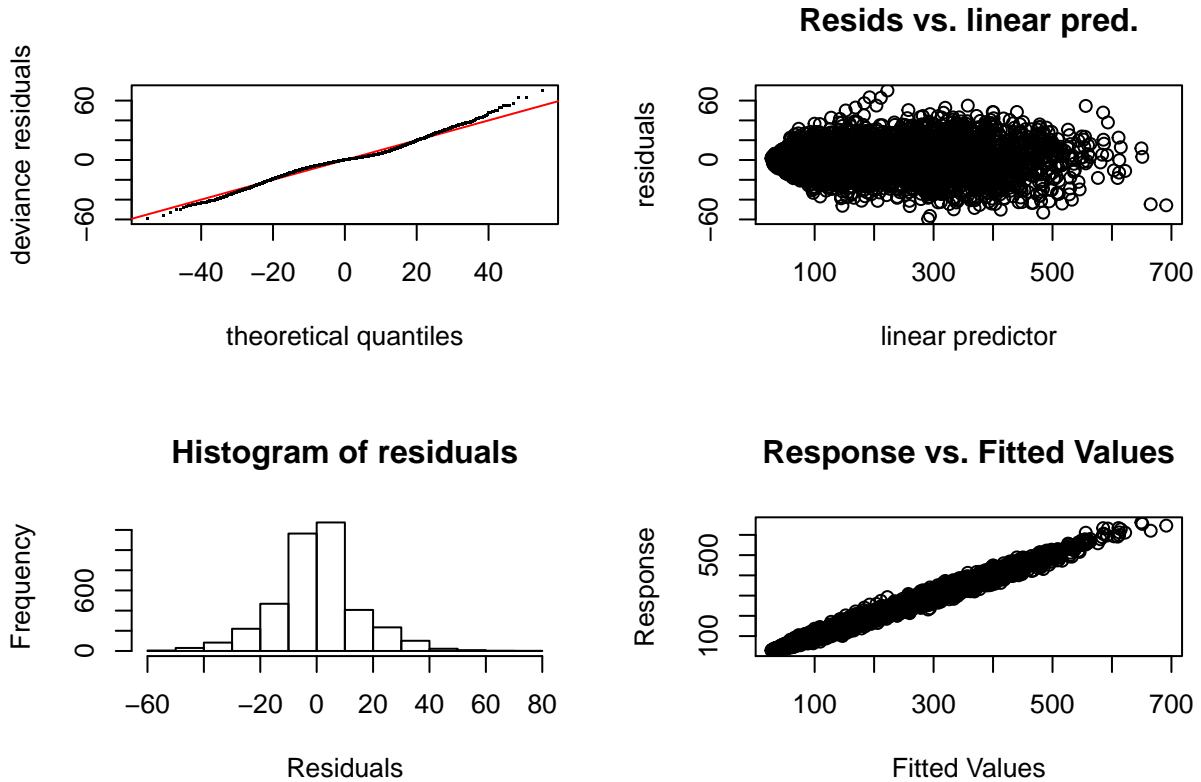


```
##
## Method: REML   Optimizer: outer newton
## full convergence after 4 iterations.
## Gradient range [-0.0001830897,0.000143563]
## (score 16811.22 & scale 238.8724).
## Hessian positive definite, eigenvalue range [0.2439383,2007.114].
## Model rank = 105 / 105
##
## Basis dimension (k) checking results. Low p-value (k-index<1) may
## indicate that k is too low, especially if edf is close to k'.
##
##           k'   edf k-index p-value
## s(tempEq)      9.00  8.38   1.01   0.81
## s(FracOfYear)  13.00 12.73   1.04   0.98
## s(trend)        6.00  5.72   0.43 <2e-16 ***
## ti(tempEq,trend) 16.00 10.02   1.00   0.59
## ti(trend,FracOfYear) 60.00 35.49   1.07   1.00
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Family: gaussian
## Link function: identity
##
## Formula:
## GWhGaz ~ s(tempEq, bs = "cr") + s(FracOfYear, bs = "cc", k = 15) +
##       s(trend, bs = "cr", k = 7) + ti(tempEq, FracOfYear, bs = c("cr",
```

```

##      "cc"), k = c(7, 7)) + ti(tempEq, trend, bs = c("cr", "cr")) +
##      ti(trend, FracOfYear, bs = c("cr", "cc"), k = c(7, 12))
##
## Parametric coefficients:
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept) 185.120      2.141  86.47  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##           edf Ref.df      F p-value
## s(tempEq)      7.834  8.453 209.199 <2e-16 ***
## s(FracOfYear) 12.654 13.000  80.042 <2e-16 ***
## s(trend)       5.720  5.961  44.295 <2e-16 ***
## ti(tempEq,FracOfYear) 16.652 30.000   8.503 <2e-16 ***
## ti(tempEq,trend)      3.425  4.196   2.043  0.0848 .
## ti(trend,FracOfYear) 39.086 60.000   4.092 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =  0.989   Deviance explained = 98.9%
## -REML = 16713   Scale est. = 225.02    n = 4018

```



```

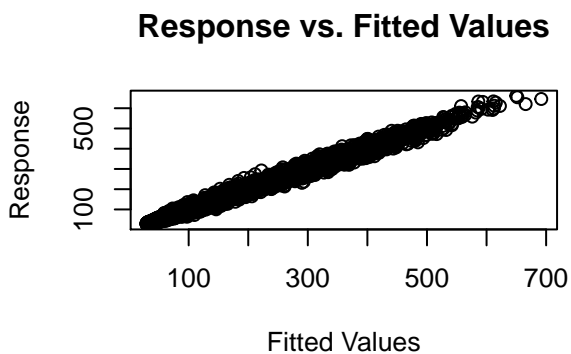
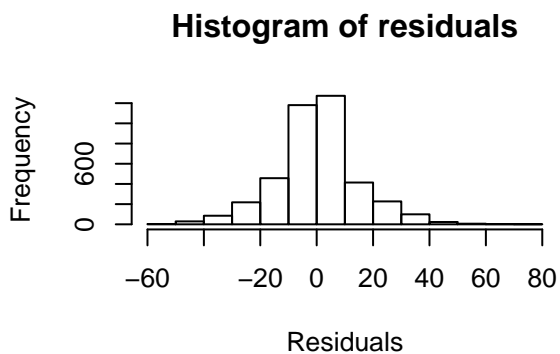
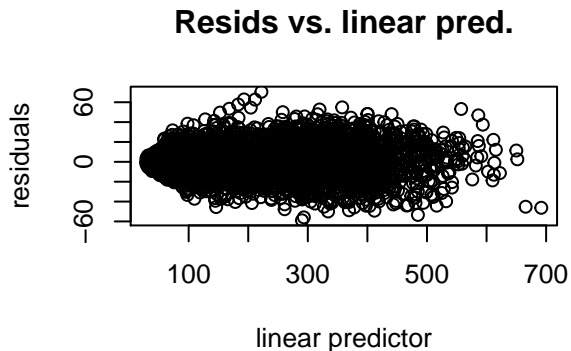
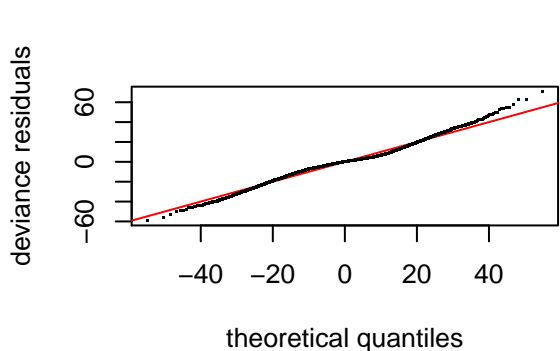
##
## Method: REML   Optimizer: outer newton
## full convergence after 6 iterations.
## Gradient range [-0.001795188,0.0175931]

```

```

## (score 16713.45 & scale 225.0204).
## Hessian positive definite, eigenvalue range [0.008932724,2007.125].
## Model rank = 135 / 135
##
## Basis dimension (k) checking results. Low p-value (k-index<1) may
## indicate that k is too low, especially if edf is close to k'.
##
##           k'   edf k-index p-value
## s(tempEq)      9.00  7.83   1.01   0.78
## s(FracOfYear)  13.00 12.65   1.02   0.93
## s(trend)       6.00  5.72   0.44 <2e-16 ***
## ti(tempEq,FracOfYear) 30.00 16.65   0.98   0.06 .
## ti(tempEq,trend)   16.00  3.43   1.00   0.40
## ti(trend,FracOfYear) 60.00 39.09   1.05   0.99
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Family: gaussian
## Link function: identity
##
## Formula:
## GWhGaz ~ s(tempEq, bs = "cr") + s(FracOfYear, bs = "cc", k = 15) +
##       s(trend, bs = "cr", k = 7) + ti(tempEq, FracOfYear, bs = c("cr",
##       "cc"), k = c(7, 7)) + ti(tempEq, trend, bs = c("cr", "cr")) +
##       ti(trend, FracOfYear, bs = c("cr", "cc"), k = c(7, 12)) +
##       ti(tempEq, FracOfYear, trend, bs = c("cr", "cc", "cr"))
##
## Parametric coefficients:
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept)  185.047      2.031   91.11 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##           edf Ref.df      F p-value
## s(tempEq)      7.848  8.460 241.792 < 2e-16 ***
## s(FracOfYear)  12.661 13.000  84.758 < 2e-16 ***
## s(trend)       5.629  5.921  16.733 < 2e-16 ***
## ti(tempEq,FracOfYear) 16.190 30.000   8.028 < 2e-16 ***
## ti(tempEq,trend)   3.053  3.457   1.335 0.164905
## ti(trend,FracOfYear) 39.777 60.000   4.181 < 2e-16 ***
## ti(tempEq,FracOfYear,trend) 6.919 48.000   0.426 0.000297 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) = 0.989   Deviance explained = 98.9%
## -REML = 16710   Scale est. = 223.74   n = 4018

```



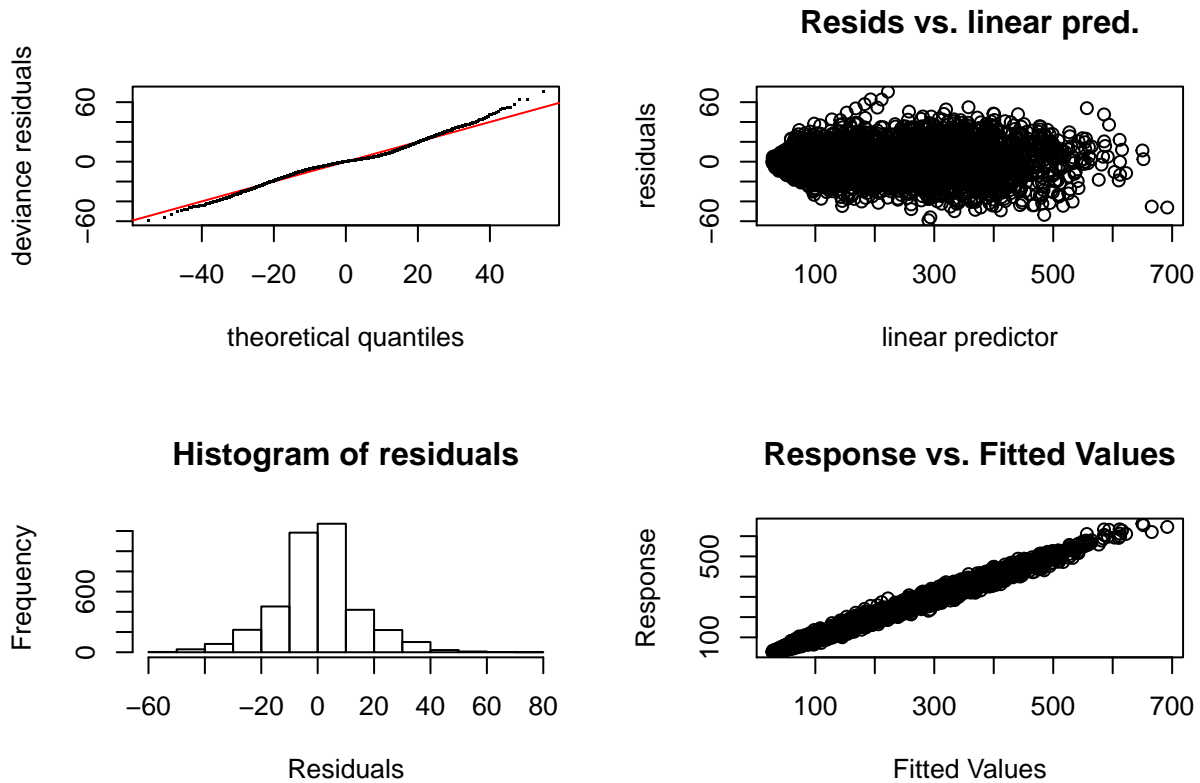
```
##
## Method: REML   Optimizer: outer newton
## full convergence after 9 iterations.
## Gradient range [-0.00420343,0.04220725]
## (score 16710.13 & scale 223.7352).
## Hessian positive definite, eigenvalue range [0.0009391262,2007.109].
## Model rank = 183 / 183
##
## Basis dimension (k) checking results. Low p-value (k-index<1) may
## indicate that k is too low, especially if edf is close to k'.
##
##           k'   edf k-index p-value
## s(tempEq)      9.00  7.85   1.01   0.73
## s(FracOfYear) 13.00 12.66   1.02   0.90
## s(trend)       6.00  5.63   0.45 <2e-16 ***
## ti(tempEq,FracOfYear) 30.00 16.19   0.98   0.11
## ti(tempEq,trend) 16.00  3.05   1.00   0.45
## ti(trend,FracOfYear) 60.00 39.78   1.05   1.00
## ti(tempEq,FracOfYear,trend) 48.00  6.92   0.99   0.28
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Family: gaussian
## Link function: identity
##
## Formula:
```

```

## GWhGaz ~ s(tempEq, bs = "cr") + s(FracOfYear, bs = "cc", k = 15) +
##   s(trend, bs = "cr", k = 7) + ti(tempEq, FracOfYear, bs = c("cr",
##   "cc"), k = c(7, 7)) + ti(tempEq, trend, bs = c("cr", "cr")) +
##   ti(trend, FracOfYear, bs = c("cr", "cc"), k = c(7, 12)) +
##   ti(tempEq, FracOfYear, trend, bs = c("cr", "cc", "cr"))
##
## Parametric coefficients:
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept) 185.047      2.031   91.11 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##           edf Ref.df      F p-value
## s(tempEq)      7.848  8.460 241.792 < 2e-16 ***
## s(FracOfYear) 12.661 13.000  84.758 < 2e-16 ***
## s(trend)       5.629  5.921  16.733 < 2e-16 ***
## ti(tempEq,FracOfYear) 16.190 30.000   8.028 < 2e-16 ***
## ti(tempEq,trend)   3.053  3.457   1.335 0.164905
## ti(trend,FracOfYear) 39.777 60.000   4.181 < 2e-16 ***
## ti(tempEq,FracOfYear,trend) 6.919 48.000   0.426 0.000297 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) = 0.989  Deviance explained = 98.9%
## -REML = 16710  Scale est. = 223.74    n = 4018
##
## Family: gaussian
## Link function: identity
##
## Formula:
## GWhGaz ~ s(tempEq, bs = "cr") + s(FracOfYear, bs = "cc", k = 15) +
##   s(trend, bs = "cr", k = 7) + ti(tempEq, FracOfYear, bs = c("cr",
##   "cc"), k = c(7, 7)) + ti(trend, FracOfYear, bs = c("cr",
##   "cc"), k = c(7, 12)) + ti(tempEq, FracOfYear, trend, bs = c("cr",
##   "cc", "cr"))
##
## Parametric coefficients:
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept) 184.91      2.04   90.66 <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##           edf Ref.df      F p-value
## s(tempEq)      7.825  8.444 237.870 < 2e-16 ***
## s(FracOfYear) 12.655 13.000  83.452 < 2e-16 ***
## s(trend)       5.600  5.907  15.959 3.01e-16 ***
## ti(tempEq,FracOfYear) 16.285 30.000   8.230 < 2e-16 ***
## ti(trend,FracOfYear) 39.981 60.000   6.479 < 2e-16 ***
## ti(tempEq,FracOfYear,trend) 9.217 48.000   0.524 9.87e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```

```
##
## R-sq.(adj) = 0.989   Deviance explained = 98.9%
## -REML = 16714   Scale est. = 223.93   n = 4018
```



```
##
## Method: REML   Optimizer: outer newton
## full convergence after 9 iterations.
## Gradient range [-0.002335024,0.01098266]
## (score 16714.34 & scale 223.9322).
## Hessian positive definite, eigenvalue range [0.002418728,2007.642].
## Model rank = 167 / 167
##
## Basis dimension (k) checking results. Low p-value (k-index<1) may
## indicate that k is too low, especially if edf is close to k'.
##
##           k'   edf k-index p-value
## s(tempEq)      9.00  7.83   1.01  0.785
## s(FracOfYear) 13.00 12.66   1.02  0.885
## s(trend)       6.00  5.60   0.45 <2e-16 ***
## ti(tempEq,FracOfYear) 30.00 16.28   0.98  0.085 .
## ti(trend,FracOfYear) 60.00 39.98   1.05  1.000
## ti(tempEq,FracOfYear,trend) 48.00  9.22   0.99  0.225
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

## Comparison AIC

```
##           df      AIC
## gas2    29.20269 33831.02
## gas3    47.15273 33620.17
## gas4    41.16903 33645.79
## gas5    68.09624 33510.24
## gas6    58.84221 33431.59
## gas7    87.91860 33265.58
## gas8    80.12823 33491.11
## gas9    97.17889 33271.89
## gas10  101.19154 33250.04
## gas11  108.63903 33269.00
```

## Add Holiday and WeekDay

### Only WeekDay

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## GWhGaz ~ s(tempEq, bs = "cr") + s(FracOfYear, bs = "cc", k = 15) +
##   s(trend, bs = "cr", k = 7) + ti(tempEq, FracOfYear, bs = c("cr",
## "cc"), k = c(7, 7)) + ti(tempEq, trend, bs = c("cr", "cr")) +
##   ti(trend, FracOfYear, bs = c("cr", "cc"), k = c(7, 12)) +
##   ti(tempEq, FracOfYear, trend, bs = c("cr", "cc", "cr")) +
##   as.factor(WeekDay)
##
## Parametric coefficients:
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept)      189.7798     1.9214  98.774 <2e-16 ***
## as.factor(WeekDay)Mon    0.9176     0.7773   1.180  0.2379
## as.factor(WeekDay)Sat  -13.2560     0.7760 -17.083 <2e-16 ***
## as.factor(WeekDay)Sun  -16.1307     0.7769 -20.763 <2e-16 ***
## as.factor(WeekDay)Thu   0.7121     0.7759   0.918  0.3588
## as.factor(WeekDay)Tue   0.9884     0.7774   1.271  0.2037
## as.factor(WeekDay)Wed   1.4159     0.7765   1.823  0.0683 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##           edf Ref.df      F p-value
## s(tempEq)      7.977  8.534 282.628 < 2e-16 ***
## s(FracOfYear)  12.742 13.000 109.780 < 2e-16 ***
## s(trend)        5.696  5.922  18.223 < 2e-16 ***
## ti(tempEq,FracOfYear) 16.378 30.000   8.837 < 2e-16 ***
## ti(tempEq,trend)    3.626  4.030   2.791  0.0225 *
## ti(trend,FracOfYear) 43.772 60.000   4.827 < 2e-16 ***
## ti(tempEq,FracOfYear,trend) 13.420 48.000   0.775 9.53e-07 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
## R-sq.(adj) = 0.992   Deviance explained = 99.2%
## -REML = 16203   Scale est. = 172.4     n = 4018
```

### Only Holiday

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## GWhGaz ~ s(tempEq, bs = "cr") + s(FracOfYear, bs = "cc", k = 15) +
##   s(trend, bs = "cr", k = 7) + ti(tempEq, trend, bs = c("cr",
##   "cr")) + ti(tempEq, FracOfYear, bs = c("cr", "cc"), k = c(7,
##   7)) + ti(trend, FracOfYear, bs = c("cr", "cc"), k = c(7,
##   12)) + ti(tempEq, FracOfYear, trend, bs = c("cr", "cc", "cr")) +
##   as.factor(Holiday)
##
## Parametric coefficients:
##
##           Estimate Std. Error t value Pr(>|t|)
## (Intercept)      178.3703     2.6539  67.210 < 2e-16 ***
## as.factor(Holiday)No         6.6664     1.6848   3.957 7.73e-05 ***
## as.factor(Holiday)SummerHoliday    7.3970     2.5995   2.846 0.00446 **
## as.factor(Holiday)WeekHoliday     0.8135     2.7692   0.294 0.76894
## as.factor(Holiday)WinterHoliday    2.3804     2.5045   0.950 0.34194
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##
##           edf Ref.df      F p-value
## s(tempEq)          7.832  8.449 241.714 < 2e-16 ***
## s(FracOfYear)     12.495 13.000  73.131 < 2e-16 ***
## s(trend)           5.616  5.918  16.343 < 2e-16 ***
## ti(tempEq,trend)   3.186  3.562   1.352  0.153
## ti(tempEq,FracOfYear) 16.277 30.000   7.962 < 2e-16 ***
## ti(trend,FracOfYear) 39.577 60.000   4.157 < 2e-16 ***
## ti(tempEq,FracOfYear,trend) 7.224 48.000   0.492 6.91e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) = 0.989   Deviance explained = 98.9%
## -REML = 16690   Scale est. = 222.58     n = 4018
```

### Both

```
##
## Family: gaussian
## Link function: identity
##
## Formula:
## GWhGaz ~ s(tempEq, bs = "cr") + s(FracOfYear, bs = "cc", k = 15) +
##   s(trend, bs = "cr", k = 7) + ti(tempEq, FracOfYear, bs = c("cr",
##   "cc"), k = c(7, 7)) + ti(trend, FracOfYear, bs = c("cr",
```

```

##      "cc"), k = c(7, 12)) + ti(tempEq, trend, bs = c("cr", "cr")) +
##      ti(tempEq, FracOfYear, trend, bs = c("cr", "cc", "cr"), k = c(7,
##      7, 7)) + as.factor(WeekDay) + as.factor(Holiday)
##
## Parametric coefficients:
##
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)      186.1172     2.4529  75.877 < 2e-16 ***
## as.factor(WeekDay)Mon          0.9796     0.7625   1.285 0.198944
## as.factor(WeekDay)Sat        -13.7673     0.7630 -18.044 < 2e-16 ***
## as.factor(WeekDay)Sun        -16.7000     0.7647 -21.838 < 2e-16 ***
## as.factor(WeekDay)Thu          0.9205     0.7601   1.211 0.225977
## as.factor(WeekDay)Tue          0.9072     0.7617   1.191 0.233696
## as.factor(WeekDay)Wed          1.3955     0.7610   1.834 0.066743 .
## as.factor(Holiday)No          3.9613     1.4823   2.672 0.007563 **
## as.factor(Holiday)SummerHoliday  2.4152     2.2837   1.058 0.290311
## as.factor(Holiday)WeekHoliday  -6.9138     2.4192  -2.858 0.004288 **
## as.factor(Holiday)WinterHoliday -7.5706     2.2123  -3.422 0.000628 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##
##              edf   Ref.df       F p-value
## s(tempEq)          7.938    8.498 270.380 < 2e-16 ***
## s(FracOfYear)     12.571   13.000  91.962 < 2e-16 ***
## s(trend)           5.551    5.754  10.781 7.1e-09 ***
## ti(tempEq,FracOfYear) 16.435   30.000   8.445 < 2e-16 ***
## ti(trend,FracOfYear) 40.771   60.000   3.829 < 2e-16 ***
## ti(tempEq,trend)     1.693    1.933   0.219  0.774
## ti(tempEq,FracOfYear,trend) 52.068  180.000   0.883 < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =  0.992   Deviance explained = 99.2%
## -REML = 16135   Scale est. = 164.85    n = 4018

```

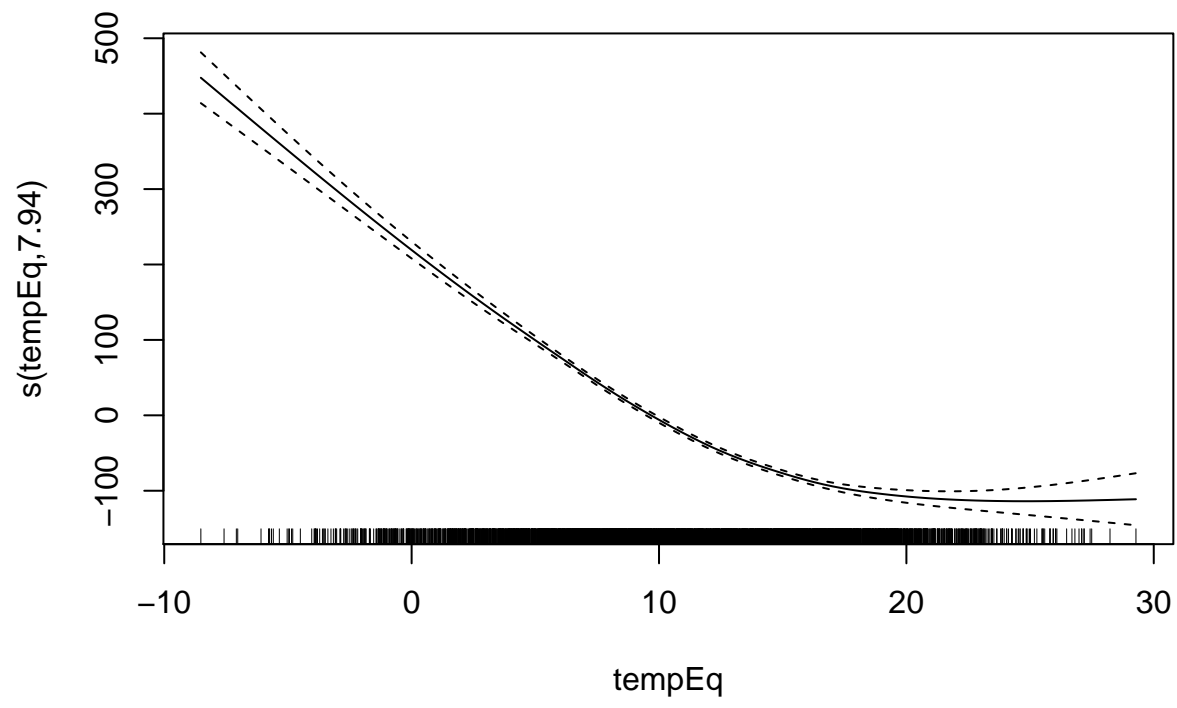
## AIC in order to select the model

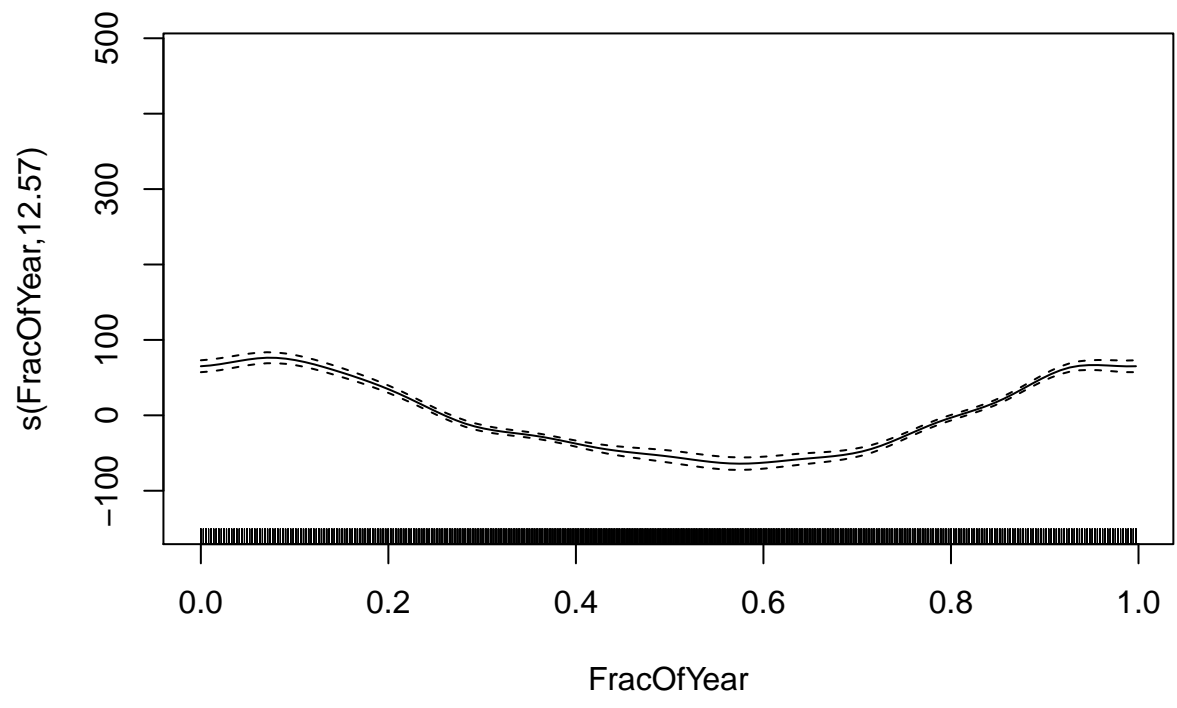
```

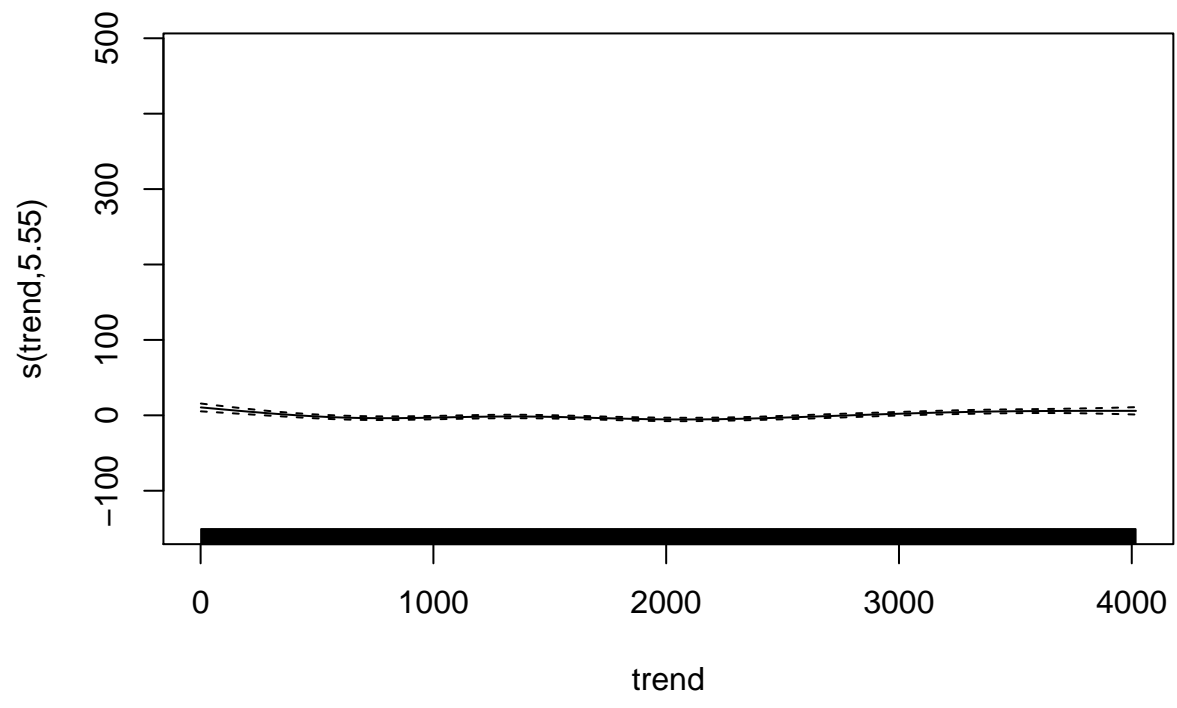
##              df      AIC
## gas10 101.1915 33250.04
## gas12 126.8763 32236.16
## gas13 104.8506 33232.38
## gas14 159.7659 32083.26

```

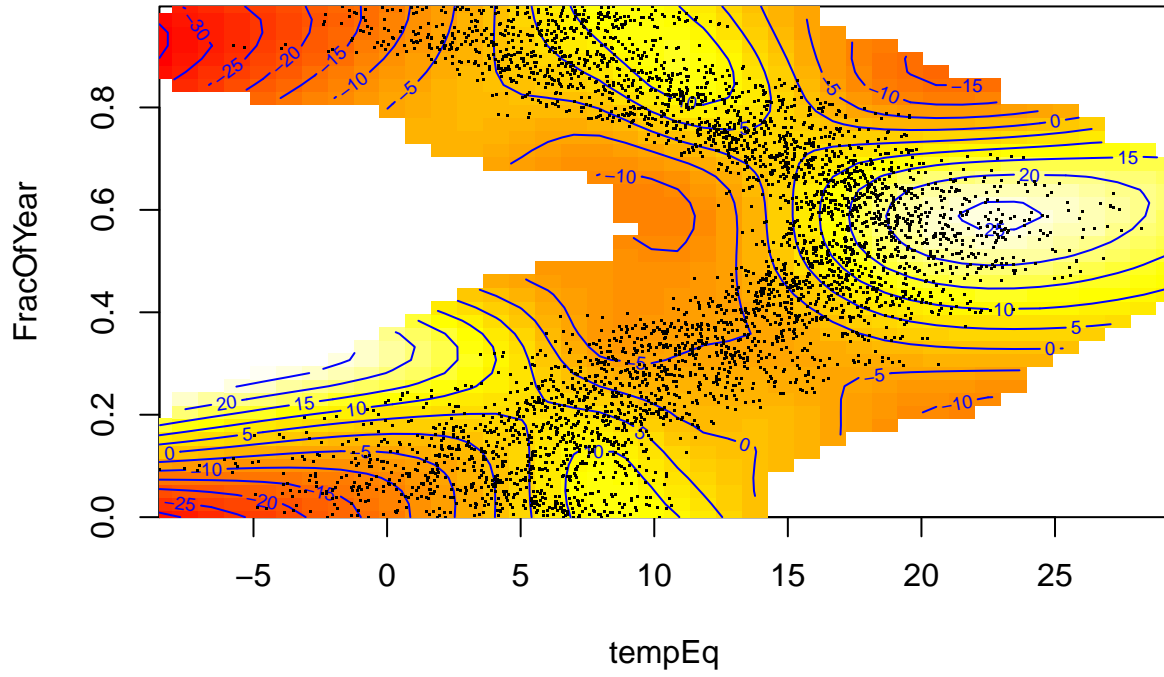
One choose gas14: weekday and holiday variable are kept ##Visualisation



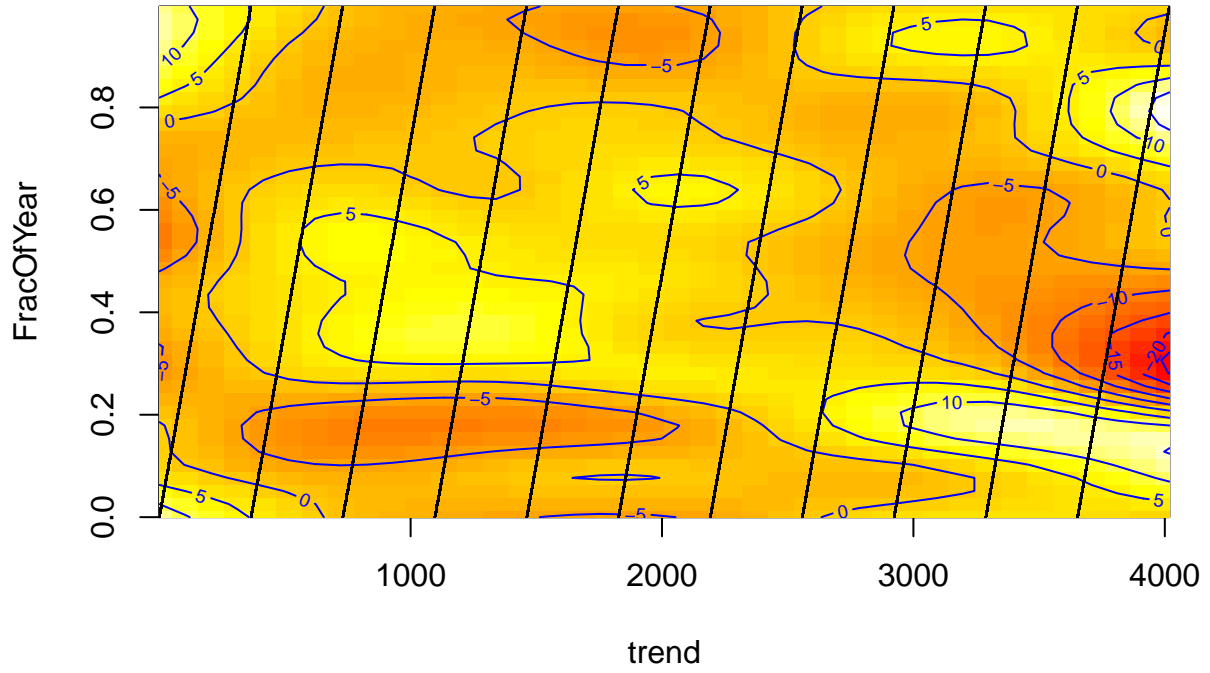




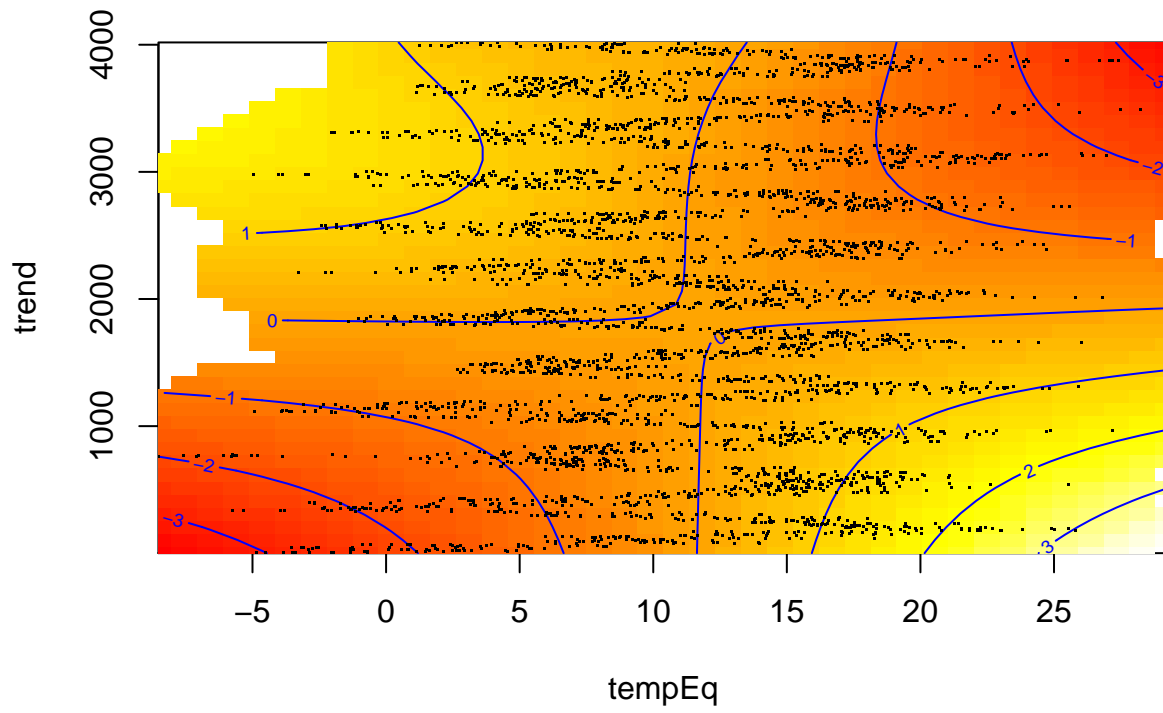
**ti(tempEq,FracOfYear,16.43)**

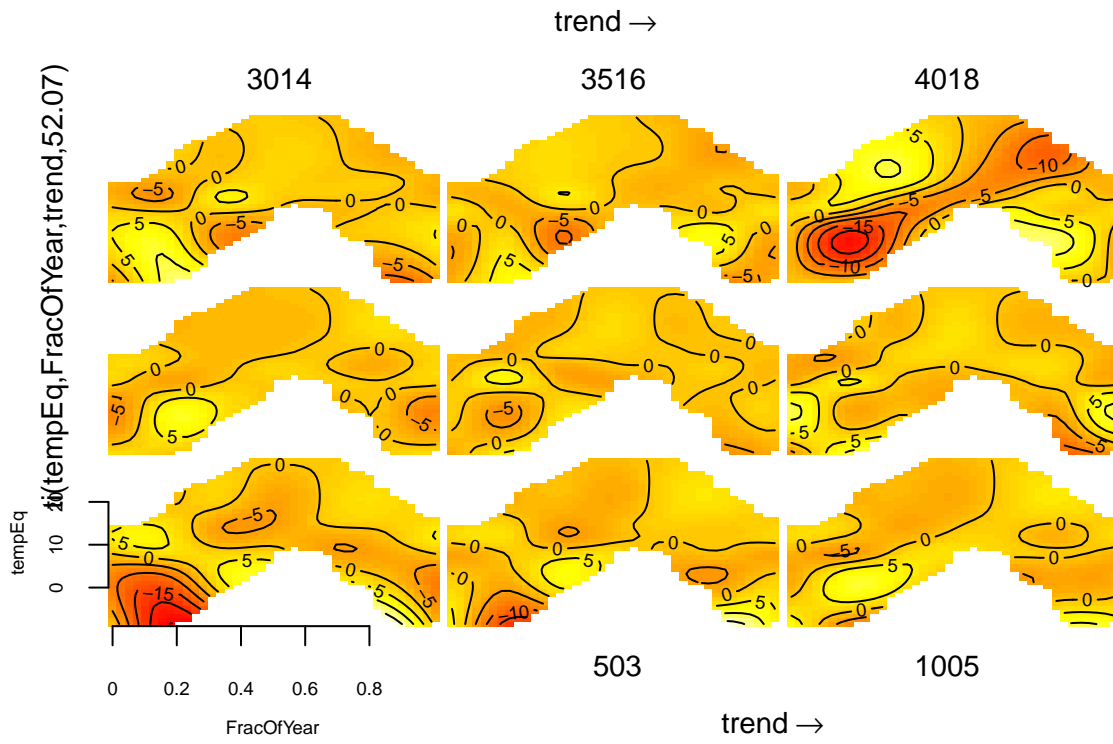


**ti(trend,FracOfYear,40.77)**

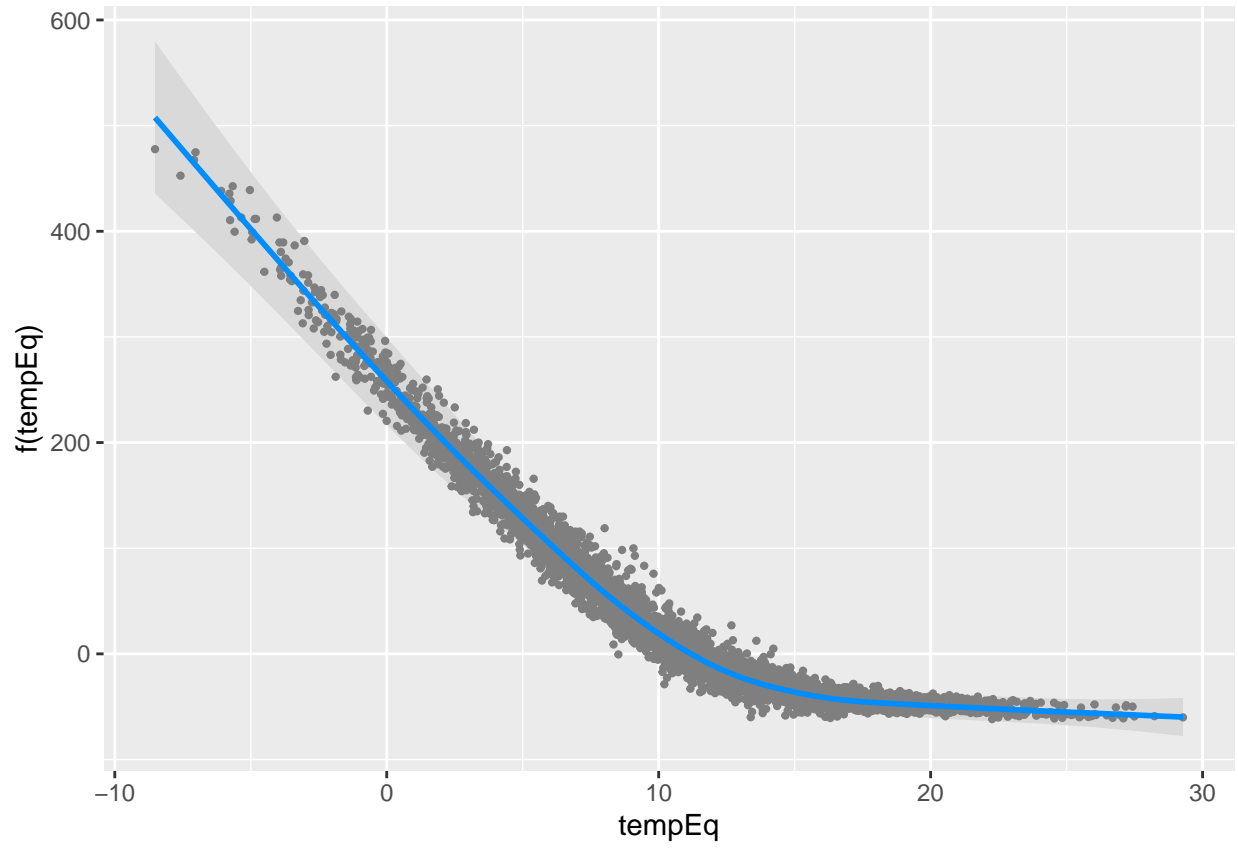


ti(tempEq,trend,1.69)

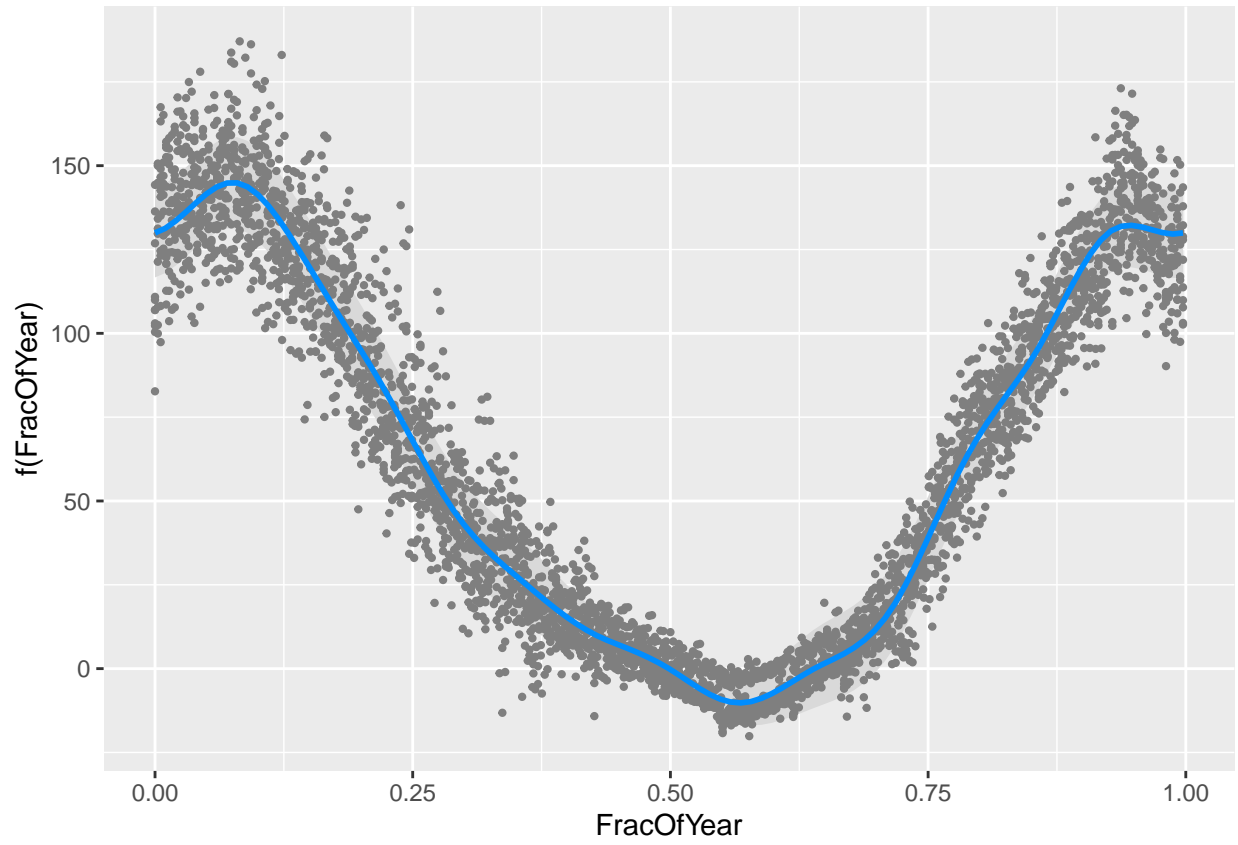




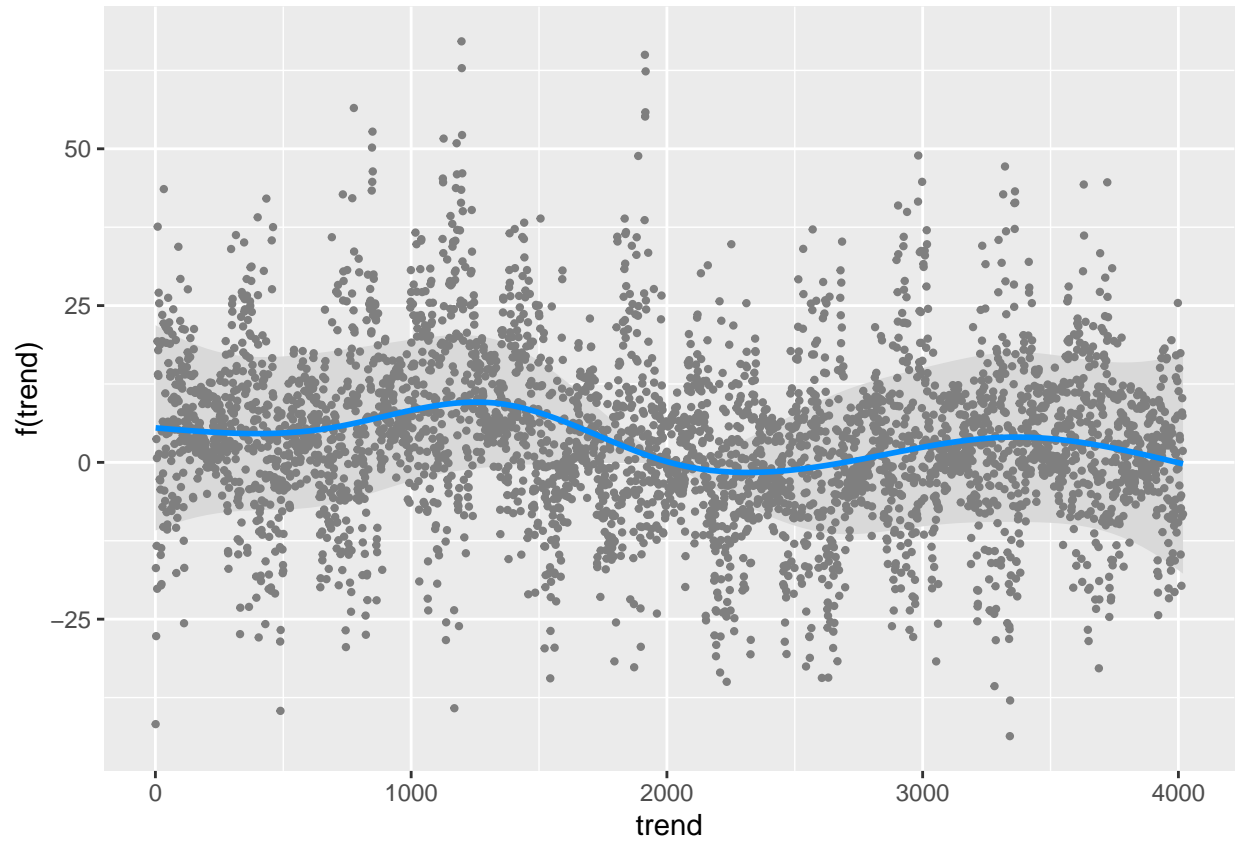
## [[1]]



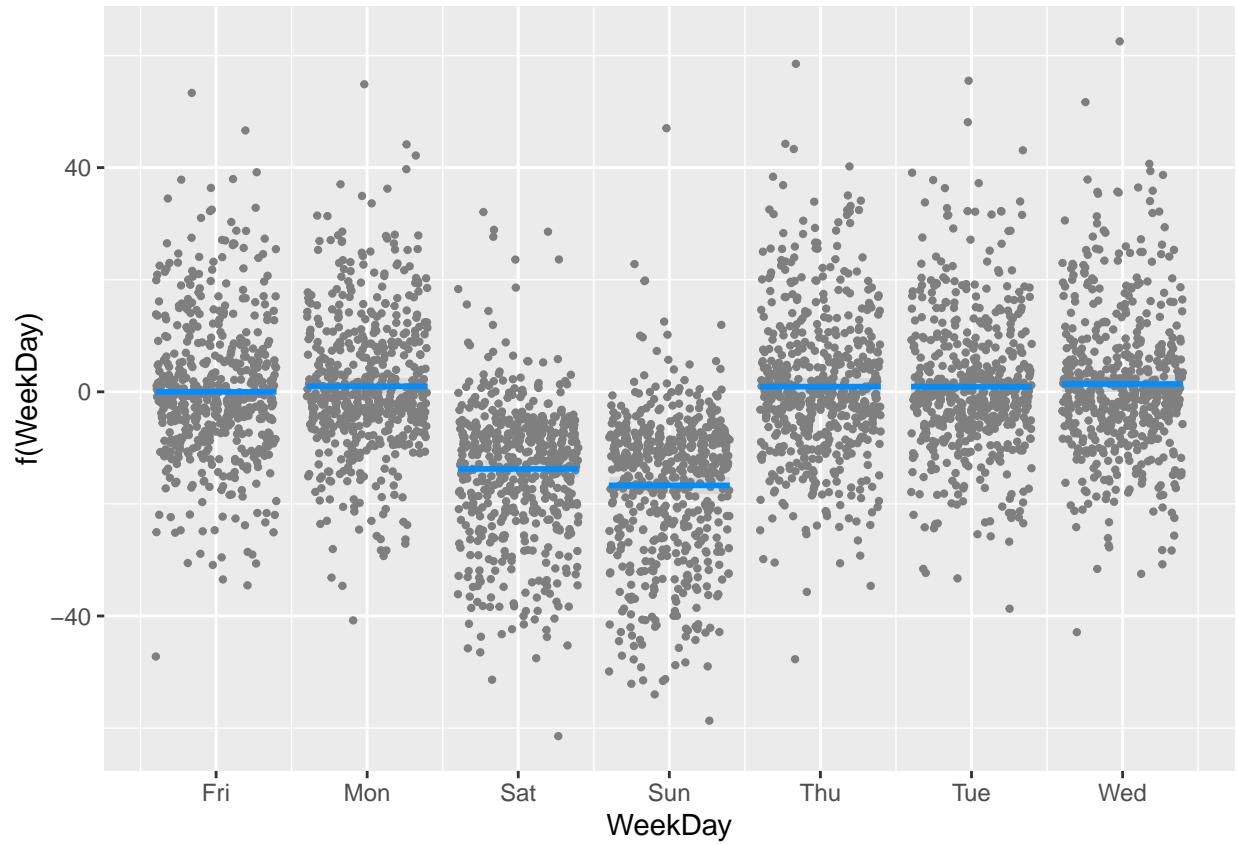
```
##  
## [[2]]
```



```
##  
## [[3]]
```



```
##  
## [[4]]
```



```
##  
## [[5]]
```

