Projet Modèle de Prévision du Pic d'Ozone

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Prise en charge des données

```
colnames(ozone)          #Affiché les noms des variables
```

```
##  [1] "JOUR"    "O3obs"   "MOCAGE"  "TEMPE"   "RMH2O"   "NO2"     "NO"
##  [8] "STATION" "VentMOD" "VentANG"
```

Type de variables :

JOUR : variable binaire qualitative O3obs : variable quantitave MOCAGE : variable quantitave TEMPE : variable quantitave RMH2O : variable quantitave NO2 : variable quantitave NO : variable quantitave VentMOD : variable quantitave VentANG : variable quantitave

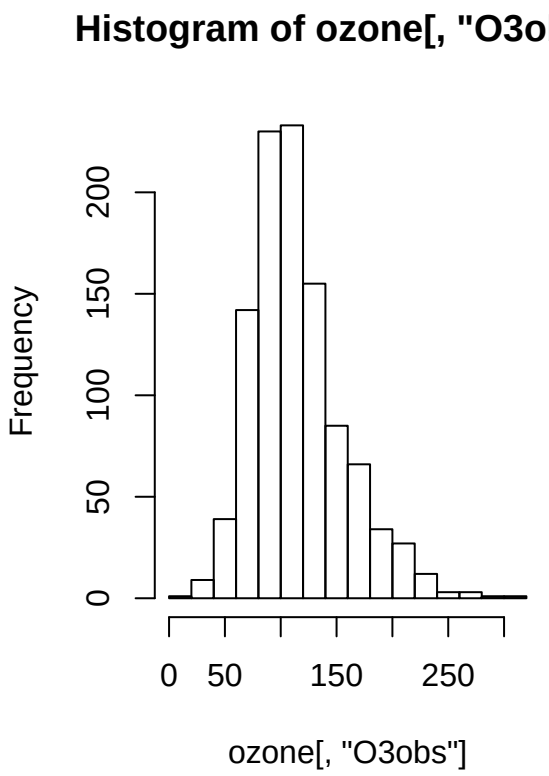
Remarque : les varaible qualitatives sont les variables ou la moyenne n'as pas de sens.

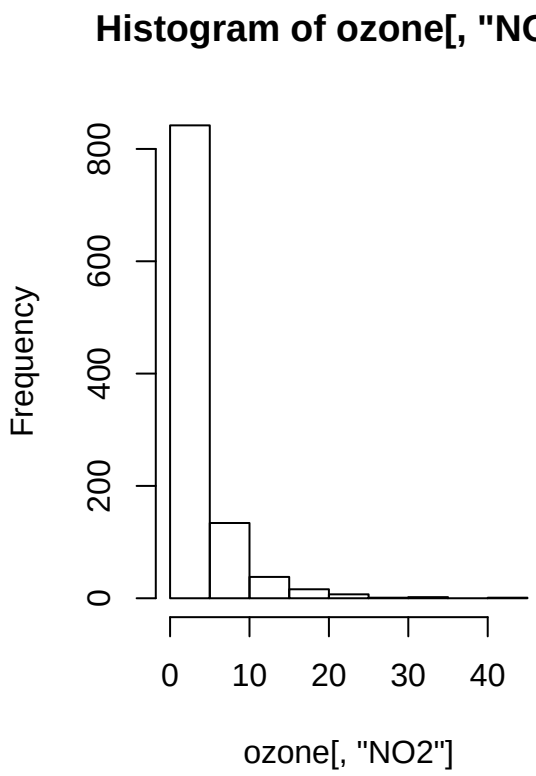
Par défaut les variables numeric sont considérés comme continues. Il est possible de les rendre discrètes en demandant une factorisation (factor()) des données. [variables binaires]

```
# Changement du type des variables qualitatives en facteur
ozone[, "JOUR"] <- as.factor(ozone[, "JOUR"])
ozone[, "STATION"] <- as.factor(ozone[, "STATION"])
#head(ozone,10)
```

Exploration élémentaire

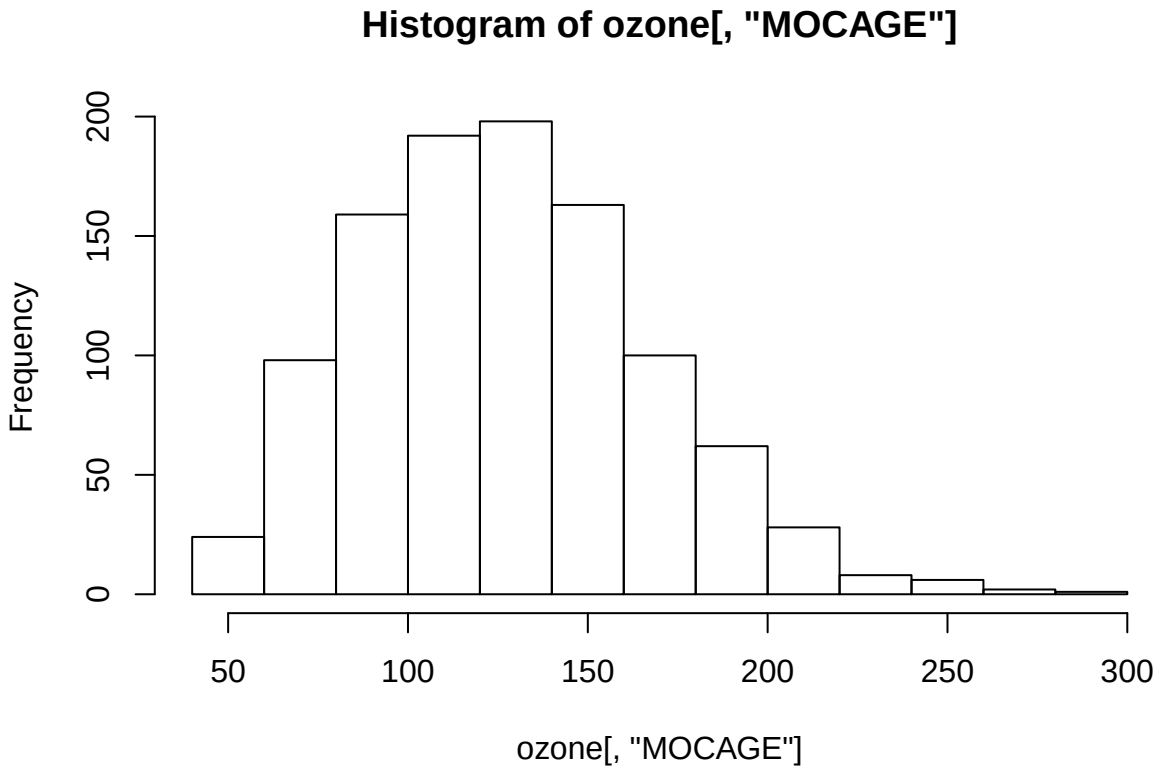
```
par(mfrow = c(1, 2))
options(repr.plot.width = 8, repr.plot.height = 4)
hist(ozone[, "O3obs"])
hist(ozone[, "NO2"])
```

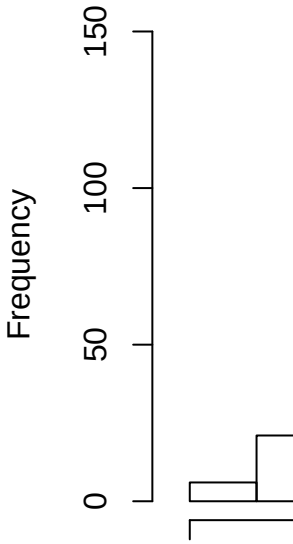


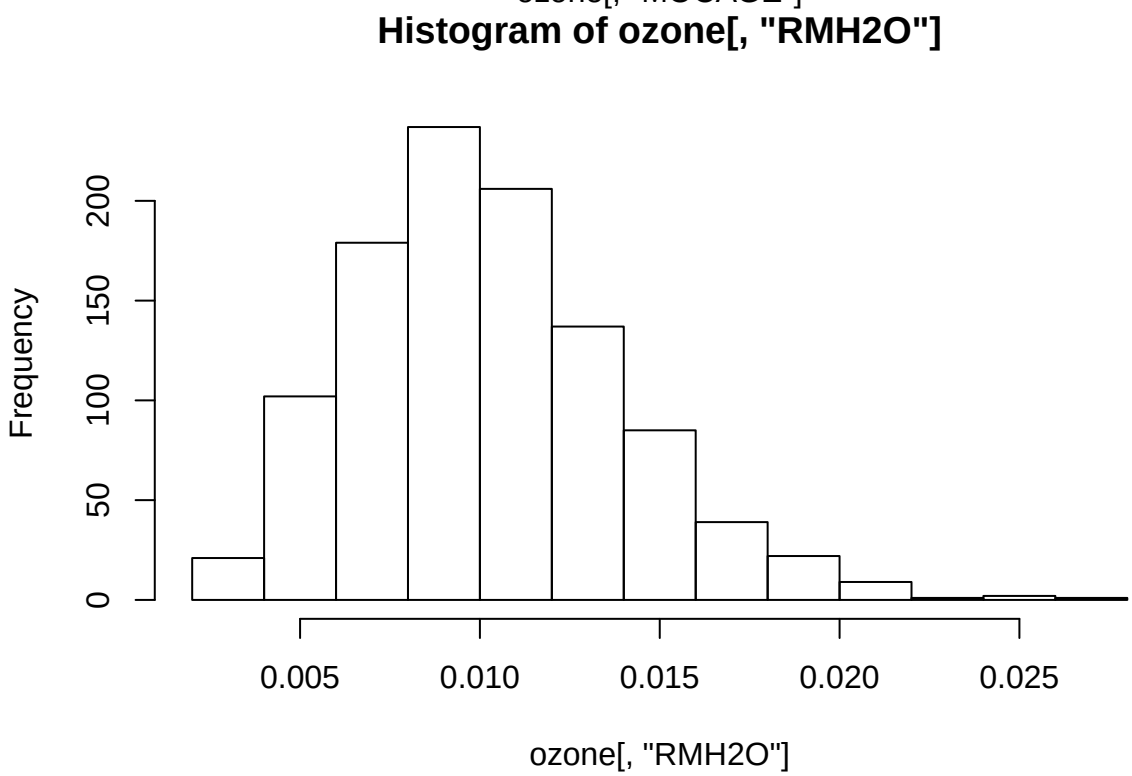


D'apres les histogrammes on remarque que les variables entre 90 et 150 sont les plus observé pour la O3obs (concentration d'ozone), et pour NO2 concentration en dioxyde d'azote entre 0 et 5. Elles ne sont pas vraiment symétriques.

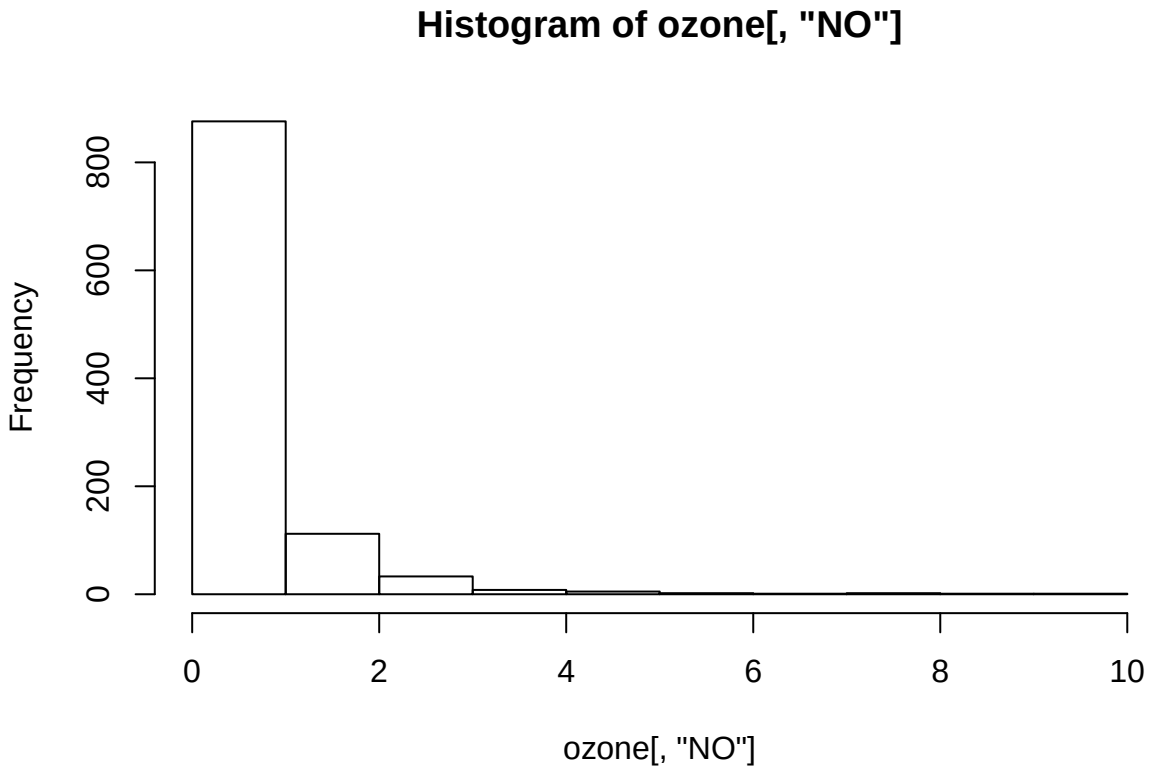
```
# Même chose pour les autres variables
 hist(ozone[,"MOCAGE"]);hist(ozone[,"TEMPE"]);hist(ozone[,"RMH2O"])
```

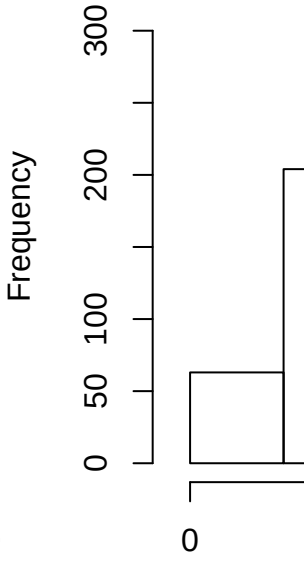


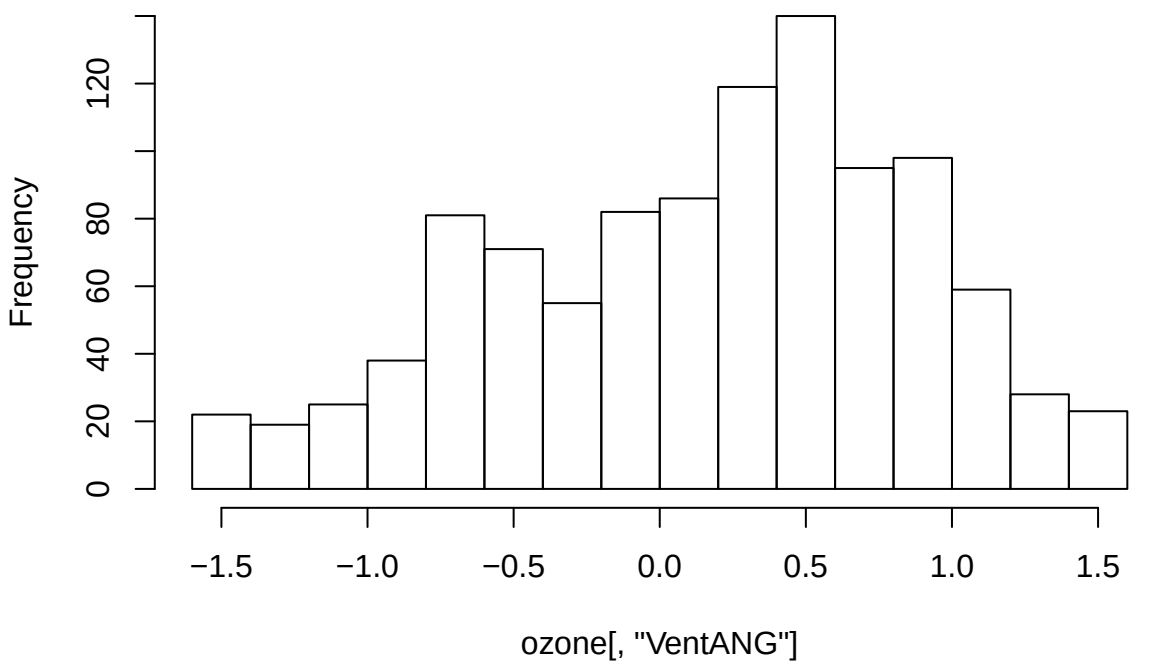





```
#
hist(ozone[,"NO"]);hist(ozone[,"VentMOD"]);hist(ozone[,"VentANG"])
```







Remarques :

-> D'après les histogrammes on remarque que la répartition de la concentration des variables O3obs, MOCAGE, RMH2O, NO2, NO, VentMOD et VentANG sont asymétriques.

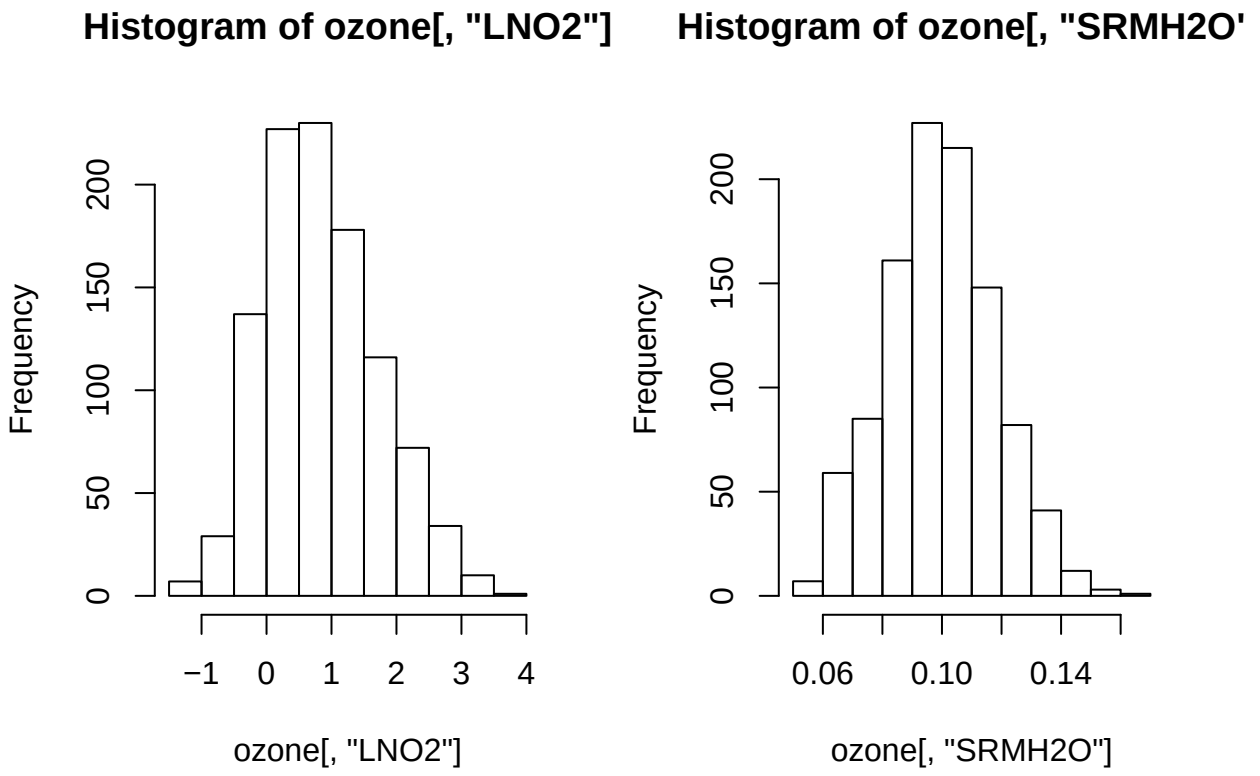
-> La répartition de TEMPE est symétrique.

Des transformations sont proposées pour rendre certaines distributions plus symétriques et ainsi plus "gaussiennes". C'est nécessaire pour certaines méthodes à venir de modélisation (linéaires), par pour toutes (arbres).

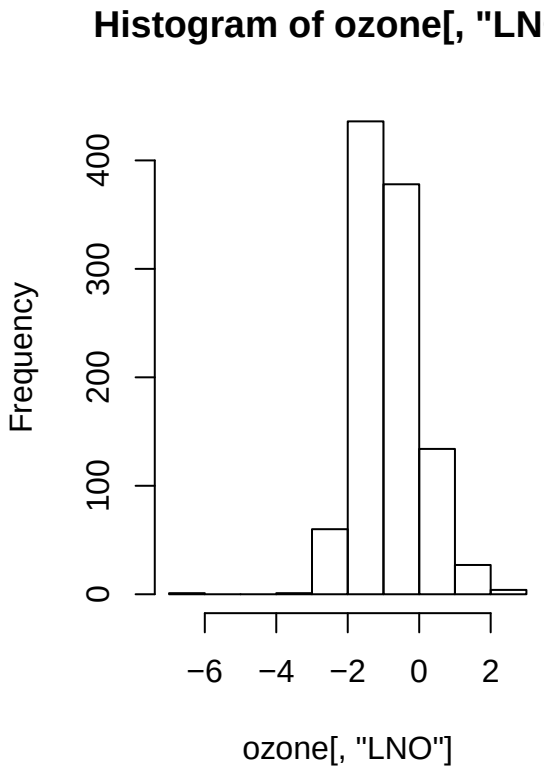
```
# Les transformation pour affiné les données
ozone[, "SRMH2O"] <- sqrt(ozone[, "RMH2O"])
ozone[, "LNO2"] <- log(ozone[, "NO2"])
ozone[, "LNO"] <- log(ozone[, "NO"])
```

Verification des transformations :

```
par(mfrow=c(1,2))
options(repr.plot.width=8, repr.plot.height=3)
hist(ozone[,"LNO2"])
hist(ozone[,"SRMH2O"])
```




```
hist(ozone[,"LNO"])
```

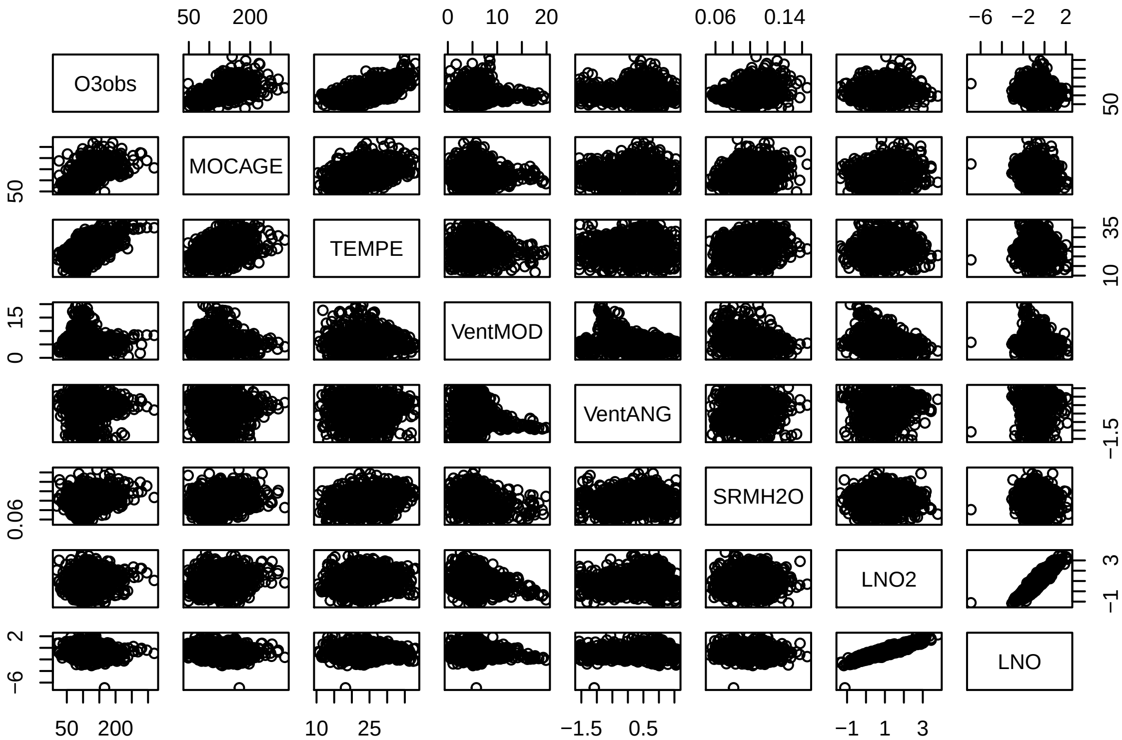


Vérifier l'opportunité de ces transformations puis retirer les variables initiales et construire la variable "dépassement de seuil" pour obtenir le fichier qui sera effectivement utilisé.

```
ozone <- ozone[, c(1:4, 8:13)]
ozone[, "DepSeuil"] <- as.factor(ozone[, "O3obs"] > 150)
summary(ozone)
```

```
##  JOUR        O3obs           MOCAGE          TEMPE       STATION
##  0:724   Min.   : 19.0   Min.   : 46.4   Min.   :10.40   Aix:199
##  1:317   1st Qu.: 87.0   1st Qu.: 97.5   1st Qu.:20.20   Als:222
##          Median :109.0   Median :125.6   Median :23.80   Cad:202
##          Mean   :115.4   Mean   :127.2   Mean   :23.88   Pla:208
##          3rd Qu.:135.0   3rd Qu.:153.6   3rd Qu.:27.60   Ram:210
##          Max.   :319.0   Max.   :284.7   Max.   :38.00
##     VentMOD           VentANG            SRMH2O             LNO2
##  Min.   : 0.1414   Min.   :-1.5708   Min.   :0.05339   Min.   :-1.3548
##  1st Qu.: 3.9623   1st Qu.:-0.3948   1st Qu.:0.08735   1st Qu.: 0.2215
##  Median : 5.5973   Median : 0.2783   Median :0.09925   Median : 0.7462
##  Mean   : 5.9072   Mean   : 0.1631   Mean   :0.09957   Mean   : 0.8440
##  3rd Qu.: 7.1063   3rd Qu.: 0.6926   3rd Qu.:0.11153   3rd Qu.: 1.4017
##  Max.   :19.8910   Max.   : 1.5708   Max.   :0.16592   Max.   : 3.7931
##       LNO           DepSeuil
##  Min.   :-6.9078   FALSE:863
##  1st Qu.:-1.4439   TRUE :178
##  Median :-0.9467
##  Mean   :-0.8399
##  3rd Qu.:-0.2957
##  Max.   : 2.2438
```

```
options(repr.plot.width = 8, repr.plot.height = 8)
pairs(ozone[, c(2:4, 6:10)])
```



Remarque : la matrice est symétrique.

Une autre méthode pour afficher la matrice de correlation et etudie les dependences entre les variables (deux à deux) ### Définition : Deux variables quantitatives sont corrélées si elles tendent à varier l'une en fonction de l'autre. On parle de corrélation positive si elles tendent à varier dans le même sens, de corrélation négative si elles tendent à varier en sens contraire.

```
library("ggplot2")
library("GGally")
```

```
## Registered S3 method overwritten by 'GGally':
##   method from
##   +.gg   ggplot2
```

```
GGally::ggpairs(ozone)        # Matrice de correlation
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.

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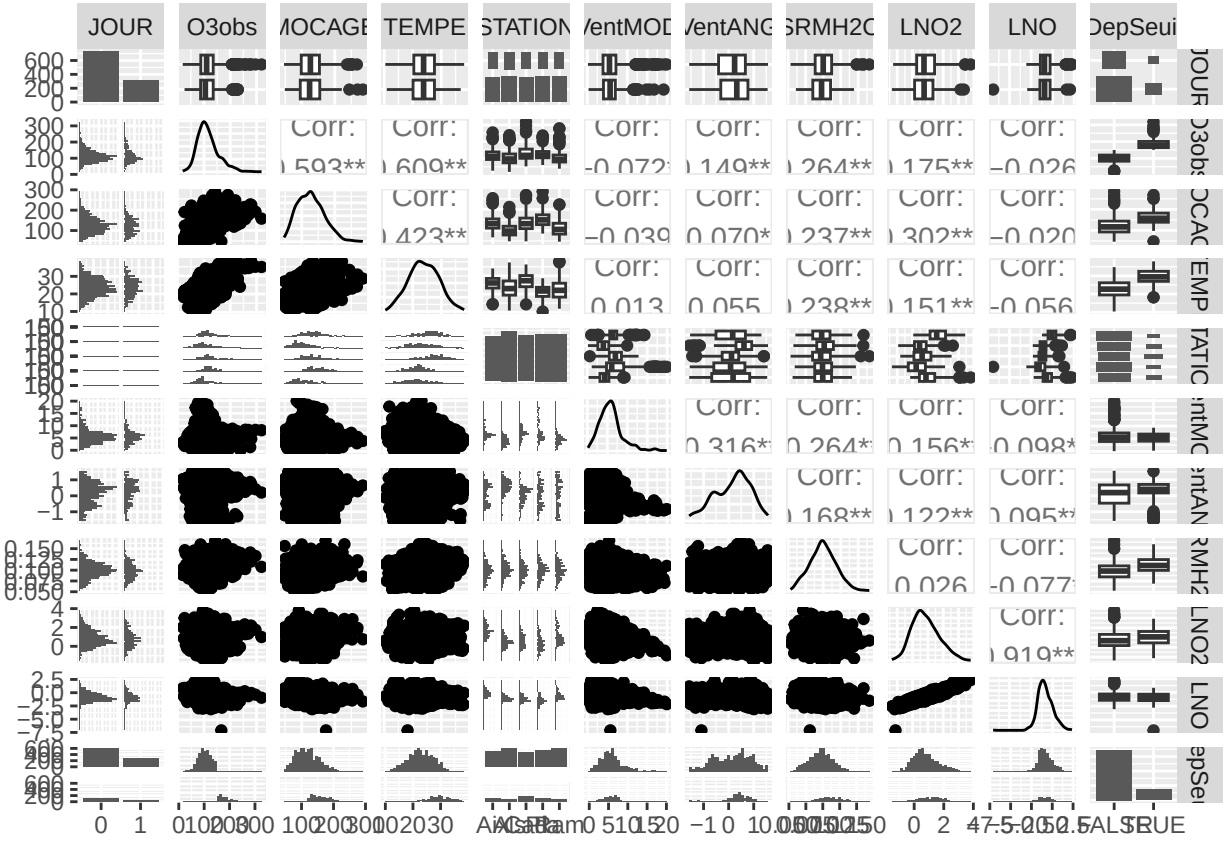

####Q-1 - Que dire sur les relations des variables 2 à 2 ?

Les deux variables les moins correler sont : VentMOD et le Tempe avec un coefficient 0,013. [variables indépendantes / corrélation nulle] Les deux variables les plus correler sont : LNO et LNO2 avec un coefficient de coerrelation 0,904. [variables liées / variables fortement correler] Tempe et O3obs avec un coefficient de coerrelation egale 0,609.

####Q-2 - Compléter en visualisant les corrélations avec la fonction 'corrplot' (package corrplot). Quelle est la limite de ce type de diagnostic numérique : quel type de corrélation est mesuré ?

```
#matrice <- cor(ozone[, c(3:4, 6:10)])
library("ggplot2")
library("GGally")
library(corrplot)
```

```
## corrplot 0.92 loaded
```

```
GGally::ggpairs(ozone)
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```

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```
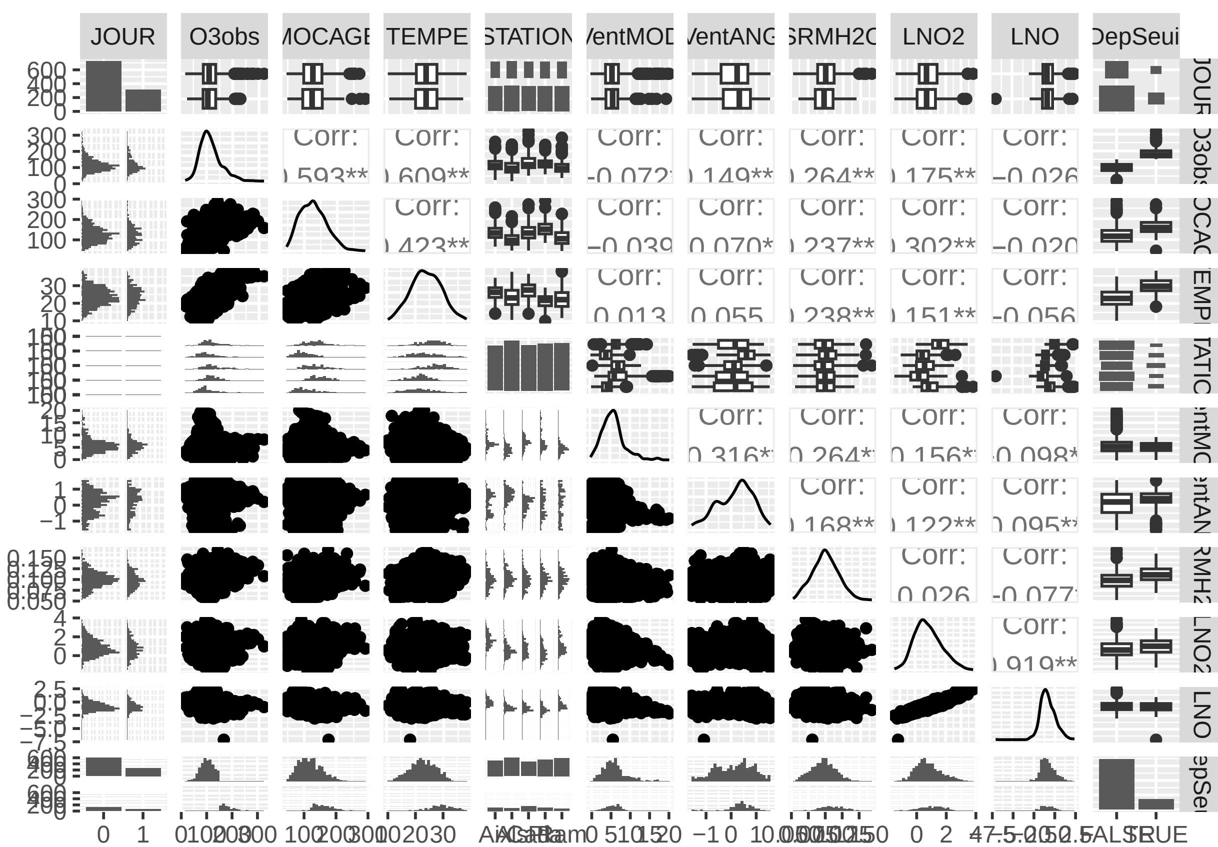
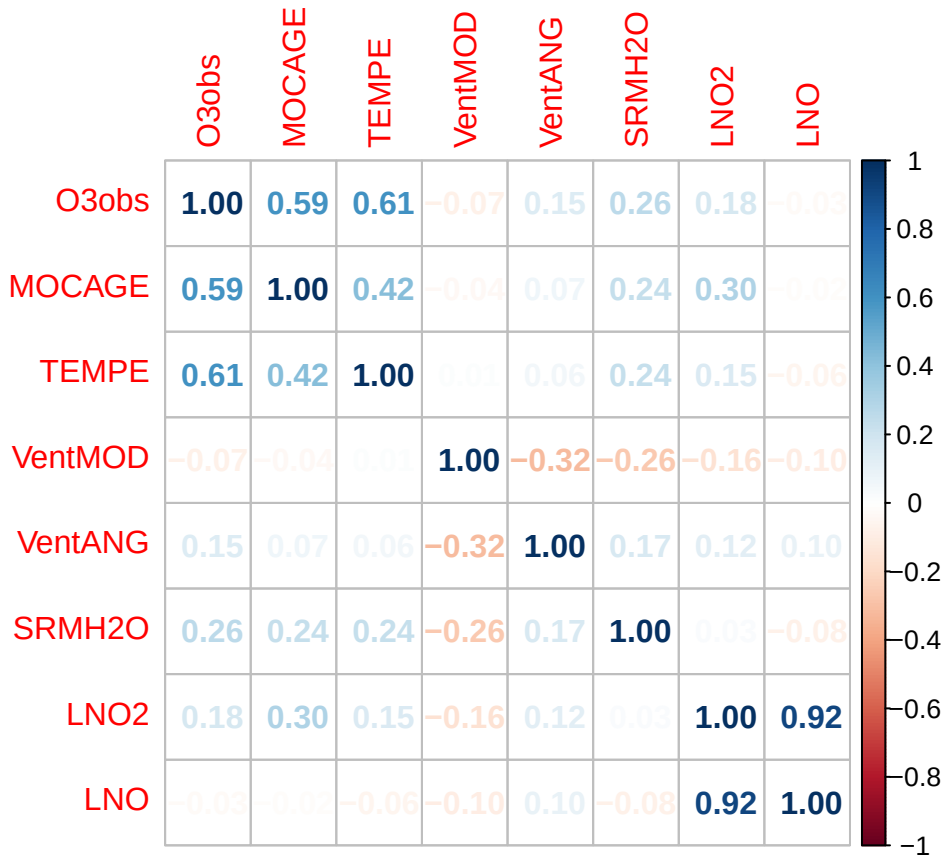




```
matrice <- cor(ozone[, c(2:4, 6:10)])
corrplot(matrice, method = 'number')
```




```
library("corrplot")
library(tidyr)
library(dplyr)
```

```
##
## Attaching package: 'dplyr'
```

```
## The following objects are masked from 'package:stats':
##
##     filter, lag
```

```
## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

```
colnames(ozone)
```

```
##  [1] "JOUR"     "O3obs"    "MOCAGE"   "TEMPE"    "STATION"  "VentMOD"
##  [7] "VentANG"  "SRMH2O"   "LNO2"     "LNO"      "DepSeuil"
```

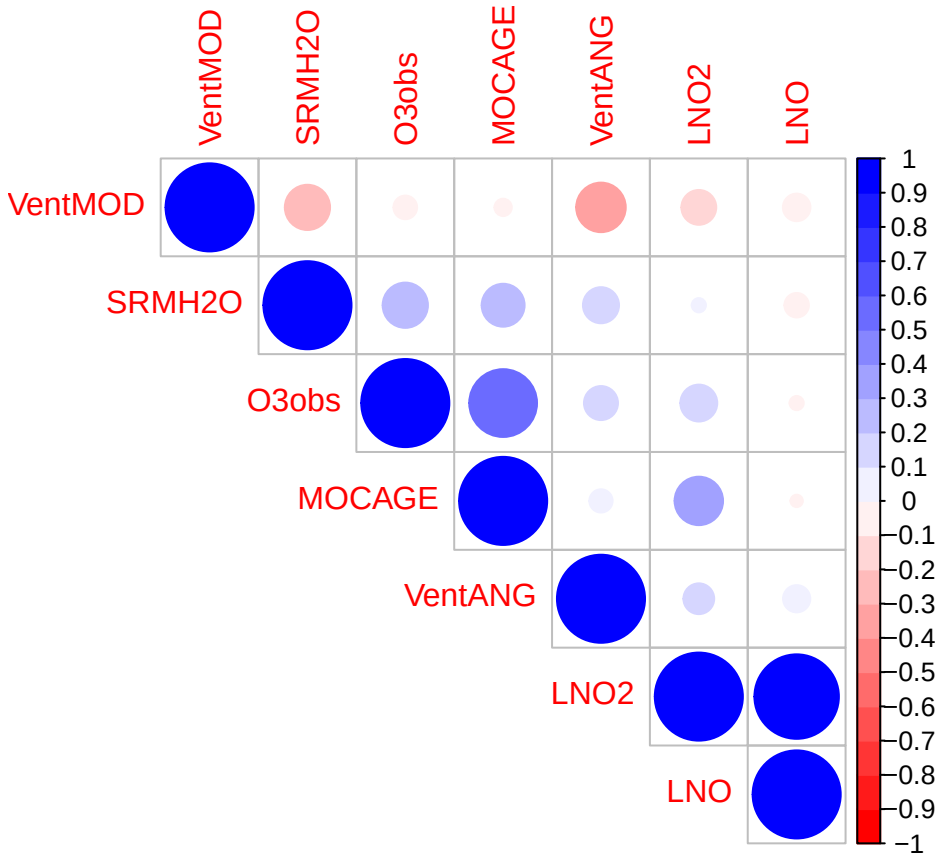
```
str(ozone)              # type de variables
```

```
## 'data.frame':    1041 obs. of  11 variables:
##  $ JOUR    : Factor w/ 2 levels "0","1": 2 2 1 1 1 1 1 2 2 1 ...
##  $ O3obs   : int  91 100 82 94 107 150 164 135 121 129 ...
##  $ MOCAGE  : num  93.2 104.6 103.6 94.8 99 ...
##  $ TEMPE   : num  21.5 20.2 17.4 18.8 23.7 23.6 26.6 23.5 23.3 23.7 ...
##  $ STATION : Factor w/ 5 levels "Aix","Als","Cad",..: 1 1 1 1 1 1 1 1 1 1 ...
##  $ VentMOD : num  9.5 8.01 9.38 9.46 7.88 ...
```

```
##  $ VentANG : num  -0.643 -0.05 -0.128 -0.345 -0.418 ...
##  $ SRMH2O  : num  0.092 0.0939 0.0975 0.0925 0.0855 ...
##  $ LNO2    : num  0.471 0.752 0.505 0.854 0.503 ...
##  $ LNO     : num  -0.858 -0.633 -0.761 -0.355 -0.794 ...
##  $ DepSeuil: Factor w/ 2 levels "FALSE","TRUE": 1 1 1 1 1 1 2 1 1 1 ...
```

```r
#cor(ozone$NO2,ozone$NO)

# selection des variables numeriques
ozone_num = ozone %>% select('O3obs', 'MOCAGE', 'SRMH2O', 'LNO2', 'LNO', 'VentMOD', 'VentANG')

# calcule de la matrice de corrélation
m <- cor(ozone_num)

# Corrélogramme : Visualisation de la matrice de corrélation
corrplot(m, method="number")
```


```r
# Utilisation de differents spectres de couleurs
col<- colorRampPalette(c("red", "white", "blue"))(20)
corrplot(m, type="upper", order="hclust", col=col)
```



* La limite de la corrélation : On ne peut pas mesurer la corrélation au-delà de deux variables comme la corrélation ne s'inquiète pas de la présence ou de l'effet d'autres variables en dehors des deux variables étudiées. Et surtout, la corrélation ne nous apprend rien sur la cause et l'effet.

** Type de correlation : Il faut parler sur la corrélation lineare (possitive/negative)

```
ozone
```

```
##      JOUR O3obs MOCAGE TEMPE STATION  VentMOD  VentANG     SRMH2O        LNO2
## 1       1    91   93.2  21.5     Aix  9.50000 -0.64350 0.09203260  0.471252849
## 2       1   100  104.6  20.2     Aix  8.01000 -0.04996 0.09386160  0.751887676
## 3       0    82  103.6  17.4     Aix  9.37710 -0.12832 0.09751923  0.505008738
## 4       0    94   94.8  18.8     Aix  9.45780 -0.34516 0.09246621  0.854415328
## 5       0   107   99.0  23.7     Aix  7.87910 -0.41822 0.08549854  0.502591819
## 6       0   150  114.3  23.6     Aix  6.31270  0.06341 0.10871982  1.670721141
## 7       0   164  127.7  26.6     Aix  4.80420  0.04164 0.09679876  1.044156103
## 8       1   135  164.3  23.5     Aix  4.87950  0.79989 0.10425929  2.755760417
## 9       1   121  144.1  23.3     Aix  5.10880  0.70226 0.10807405  2.175546860
## 10      0   129  112.8  23.7     Aix  5.44060  0.94200 0.10445095  2.939743763
## 11      0   118   72.6  22.2     Aix  5.96410 -0.60661 0.12751471  1.448799566
## 12      0    48  146.0  14.3     Aix  5.80340 -0.03447 0.12054045  2.614764637
## 13      0    97   87.5  18.5     Aix  7.52730  0.33856 0.09792855  1.417308415
## 14      1    83  158.9  15.4     Aix  2.59420  0.48089 0.12066483  2.327667873
## 15      1    73  112.6  19.6     Aix  8.87520 -0.58488 0.11045361  0.670390193
## 16      0    91   76.9  21.7     Aix 12.30040 -0.63537 0.08276473  0.323531725
## 17      0    70   81.8  24.4     Aix  9.50000 -0.64350 0.09433981  0.449162963
## 18      0   125  178.6  24.8     Aix  6.51920  0.72027 0.10981803  2.106083473
## 19      0   168  127.9  28.2     Aix  7.13090  0.38832 0.11777096  1.532988740
## 20      0   113  109.3  26.0     Aix  5.98160  0.66691 0.11045361  2.508785924
```

```
## 21      1   118  113.0  26.2     Aix  6.27690  0.53496 0.10315038  1.529311868
## 22      1   130  136.3  27.2     Aix  6.00330  0.52328 0.09549869  1.453017993
## 23      0   179  141.1  27.8     Aix  5.13130  0.57719 0.10049876  2.035489654
## 24      0   196  131.4  29.1     Aix  6.09020  0.51507 0.09586449  1.650195905
## 25      0   160  141.1  29.5     Aix  6.12210  0.66964 0.10163661  1.618001143
## 26      0   180  163.6  29.5     Aix  5.52270  0.55284 0.08882567  2.142416341
## 27      0   103  141.6  29.1     Aix  5.28390  0.51445 0.08142481  1.895218178
## 28      1   214  159.9  33.2     Aix  7.26150  0.39585 0.11962441  1.416338482
## 29      1   178  138.1  30.5     Aix  6.08770  0.73892 0.12284136  1.922056470
## 30      0   160  155.1  30.9     Aix  7.24220 -0.61864 0.12353137  0.911881023
## 31      0   131  140.5  30.2     Aix  9.00000 -0.64350 0.09364828  1.107241615
## 32      0   169  149.9  30.2     Aix  5.78010 -0.52558 0.10648944  0.787547856
## 33      0   139   92.5  26.0     Aix  5.36000  0.93103 0.11941524  3.170609523
## 34      0   104   97.9  25.4     Aix 12.39070 -0.83678 0.09402127  0.596636280
## 35      1   127   96.1  26.2     Aix  6.22660 -0.52114 0.08438009  0.576613364
## 36      1   163  123.7  25.4     Aix  6.30080  0.01587 0.10285913  0.993622075
## 37      0   121  146.2  23.3     Aix  4.78540  1.11649 0.11588788  2.903287983
## 38      0    93  126.1  26.6     Aix  6.01330 -0.06657 0.11031772  1.159080035
## 39      0   108  122.4  22.1     Aix  6.44440  0.73051 0.13682105  2.163093114
## 40      0    91   99.7  24.7     Aix 11.20580 -0.57563 0.08683317  0.746213901
## 41      0   129  122.4  24.5     Aix  6.93540  0.74460 0.09596874  1.678777391
## 42      1    89  146.5  24.9     Aix  6.57650 -0.49085 0.10648944  0.848440065
## 43      1   145  145.2  28.1     Aix  7.46530  0.68102 0.11584472  1.545645779
## 44      0   124  127.3  28.0     Aix  7.13440  1.02557 0.10597169  1.869646008
## 45      0   132  125.9  26.9     Aix  6.29360  0.77416 0.10830512  2.242197943
## 46      0    96  183.4  26.3     Aix  5.44520 -0.12891 0.12177849  1.466490903
## 47      0   116  117.0  28.9     Aix  6.36000 -0.28694 0.10034939  1.009052212
## 48      0   132  128.4  30.0     Aix  6.56200 -0.13759 0.10114346  1.033184483
## 49      1    93   74.1  24.9     Aix  9.42600 -0.71783 0.09919677  0.044016885
## 50      0   117  159.1  20.1     Aix  5.46260 -0.41451 0.14007141  1.140074078
## 51      0    96  143.3  23.7     Aix 12.10170 -0.74449 0.12385475  0.753771802
## 52      0   111  119.9  28.4     Aix 10.60420 -0.67180 0.10667708  0.600483496
## 53      0   184  168.5  29.0     Aix  6.71190 -0.05963 0.09486833  1.342081206
## 54      1   170  133.4  28.3     Aix  6.72310  0.53022 0.10899541  1.536221850
## 55      1   148  125.6  28.5     Aix  4.66150  0.61776 0.12397580  2.440606391
## 56      0   109  154.3  31.1     Aix  5.86690 -0.51703 0.09126883  1.228177493
## 57      0   222  133.9  29.5     Aix  5.70790 -0.05258 0.12066483  1.205671361
## 58      0    80   72.6  27.6     Aix 12.44830 -0.80812 0.10977249  0.049742092
## 59      0   108  105.7  25.8     Aix 12.56070 -0.70085 0.10173495  0.532978428
## 60      0   156  137.1  28.6     Aix  5.57310  0.16220 0.11207141  0.988053098
## 61      1   126  136.8  27.1     Aix  6.29680  0.81909 0.11747340  2.048337797
## 62      1   130  150.6  26.6     Aix  5.68510  0.68573 0.12557866  1.536867220
## 63      0   182  229.2  22.1     Aix  5.09310  0.81317 0.15767054  2.907064981
## 64      0   107  147.6  24.7     Aix  5.48180  0.25825 0.13099618  1.818563672
## 65      0   148  155.2  30.0     Aix  6.04400  0.67991 0.10825895  1.720442470
## 66      1   171  163.9  30.3     Aix  6.16200  0.72799 0.12004166  2.072542800
## 67      0   157  148.5  32.2     Aix  6.59470  0.71027 0.11933147  1.577327859
## 68      0   181  146.6  32.7     Aix  7.08310  0.53316 0.10728467  1.647311565
## 69      0   155  157.5  32.2     Aix  5.76890  0.58800 0.13379088  1.741342983
## 70      0   191  149.6  31.8     Aix  6.37020  0.82981 0.12328828  2.062168213
## 71      1   202  143.2  32.5     Aix  7.16100  0.62674 0.12445883  1.532124809
## 72      1   176  128.5  31.6     Aix  7.10280  0.61534 0.11541230  1.452550157
## 73      0   183  184.0  32.8     Aix  7.44040  0.63275 0.13468482  1.517322624
## 74      0   255  191.2  34.1     Aix  7.07250  0.80540 0.13011533  2.356978577
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## 75      0   185  176.9  32.6     Aix  7.28630  0.75628 0.14156271  2.361608433
## 76      0   193  207.7  32.5     Aix  6.74170  0.56332 0.13931978  2.111787718
## 77      1   197  205.9  32.1     Aix  6.53070  0.44310 0.13122500  2.045884758
## 78      0   136  126.1  32.5     Aix  7.90760 -0.16515 0.11166915  0.677017799
## 79      1   141   91.8  23.3     Aix  6.08030  0.93716 0.08449852  2.614032519
## 80      0   103  130.0  25.1     Aix  6.10330 -1.53802 0.06565059  1.891755622
## 81      0    90   95.8  21.1     Aix  8.68330 -0.50486 0.06648308  1.013780353
## 82      1    91  121.5  18.0     Aix 12.54950 -0.71208 0.07469940  1.331045887
## 83      0    93  110.1  19.8     Aix  7.30550 -0.33474 0.06107373  1.485234309
## 84      0    93  163.1  19.0     Aix  3.93190  0.12751 0.08306624  3.431855903
## 85      0   119  119.4  20.9     Aix  4.34630 -0.40187 0.06434283  1.578566249
## 86      0   124  129.6  22.0     Aix  7.51800 -0.49935 0.07543209  0.949338586
## 87      1    87  102.5  18.9     Aix  5.35350 -0.57246 0.09777525  1.576087933
## 88      1   107  116.9  20.0     Aix  6.37890  0.23737 0.07981228  1.891906418
## 89      0   106   81.4  14.5     Aix  0.94340 -0.55860 0.09843780  3.113337516
## 90      0    77  122.0  16.0     Aix  3.92050 -0.65881 0.10473777  1.563603376
## 91      0    82  101.0  15.6     Aix 11.98080 -0.65519 0.07739509  1.343908645
## 92      0    93  131.5  22.9     Aix  5.94640 -0.34302 0.06356099  1.642292249
## 93      0   117  118.1  21.6     Aix  6.43820  0.75244 0.08062258  2.971849333
## 94      1   115   93.4  22.0     Aix  6.12940  1.07796 0.07449832  2.546942041
## 95      1   117  134.9  23.2     Aix  4.82600 -0.97705 0.07348469  0.957816479
## 96      0    87  102.0  20.5     Aix 11.68250 -0.66405 0.07968689  1.059871460
## 97      0   111  117.9  24.0     Aix  6.01660 -0.26917 0.08179242  1.539444541
## 98      0   116  169.5  24.8     Aix  4.70110  0.51123 0.10908712  2.431330049
## 99      0   144  190.1  24.5     Aix  5.05670  0.42826 0.10802777  2.025249313
## 100     0   155  150.8  25.3     Aix  5.58660  0.77274 0.10104454  2.297270998
## 101     1   183  155.1  25.1     Aix  5.75850  0.35471 0.10074721  1.743094297
## 102     1   134  158.0  25.5     Aix  5.06060  0.51670 0.10222524  1.802204727
## 103     0    82  115.9  27.3     Aix  9.61770 -0.77069 0.12316655  0.929799082
## 104     0    90  106.7  24.3     Aix  5.09120 -0.78540 0.10625441  1.713257241
## 105     0   151  148.9  25.0     Aix  5.10100  0.01961 0.09746794  1.457917105
## 106     0   188  167.8  24.0     Aix  2.80710  0.07131 0.11144505  1.383791231
## 107     0   142  170.0  24.9     Aix  4.45980  0.34302 0.10751744  1.223187023
## 108     1    85  127.8  26.3     Aix  7.44040 -0.63275 0.06625708  1.053614923
## 109     1    90   94.9  25.5     Aix 10.38560 -0.67624 0.06379655  1.166893796
## 110     0    68  101.6  25.4     Aix 11.74560 -0.74927 0.07726578  1.139434283
## 111     0    98  123.6  19.5     Aix  7.02920  0.87606 0.08820431  1.911762262
## 112     0   111  106.3  21.9     Aix  5.81890 -0.33262 0.07035624  1.265820208
## 113     0   131  145.0  20.2     Aix  6.61290  0.35523 0.08282512  1.722766598
## 114     1   102  132.8  20.0     Aix  6.08770  0.83188 0.08786353  2.307672132
## 115     1   112  122.4  21.8     Aix  6.20970  1.31019 0.08294577  1.928037088
## 116     0   104  137.2  25.0     Aix  6.69100 -1.40565 0.08994443  1.601607333
## 117     0   109  156.4  25.7     Aix  6.04150 -0.50067 0.08467585  1.450207687
## 118     0   117  124.2  28.5     Aix  6.74170 -0.36398 0.09093954  0.898126761
## 119     0   139  178.4  29.3     Aix  6.53070  0.20040 0.09602083  1.355061659
## 120     1   229  173.2  28.6     Aix  5.64360  0.51915 0.09884331  1.680082752
## 121     0   169  194.6  27.5     Aix  4.38630  0.42285 0.11113055  1.525186360
## 122     0   122  177.1  29.3     Aix  5.86690  0.51703 0.10802777  1.563603376
## 123     0   163  188.8  27.3     Aix  1.58110  0.60554 0.12263768  1.477048724
## 124     0   123  163.7  27.6     Aix  4.34170  0.50486 0.10606602  2.185264450
## 125     0   116  153.5  28.2     Aix  6.72010  0.93325 0.10382678  2.659490010
## 126     1   117  152.0  28.4     Aix  6.22900  0.73997 0.09767292  2.407125272
## 127     1   118  160.1  30.3     Aix  6.32530  0.68462 0.09370165  2.030776370
## 128     0   115  165.8  31.1     Aix  6.49000  0.58800 0.09110434  2.097649761
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## 129     0    97  141.2  30.8     Aix  6.82500  0.68161 0.09612492  2.258528707
## 130     0    82  146.8  27.1     Aix  6.15220  0.79689 0.11153475  2.065089035
## 131     0   116  107.4  27.7     Aix  8.30240 -0.02409 0.09099451  0.923464936
## 132     0    64  104.7  26.0     Aix  8.80510  0.03408 0.10124228  0.719302138
## 133     0    81  111.2  25.8     Aix  8.82040 -0.57542 0.07912016  1.142629174
## 134     1   102  128.3  24.0     Aix  9.08020 -0.44395 0.08111720  0.931770303
## 135     1    89  144.3  25.6     Aix  5.98160 -0.66691 0.08613942  0.770108222
## 136     0   124  141.6  30.0     Aix  5.70090 -0.37725 0.09289779  0.932951173
## 137     0   139  186.2  28.1     Aix  6.36950  0.38634 0.09186947  1.652880470
## 138     0   176  170.3  27.1     Aix  3.60560  0.33929 0.10620734  1.221124863
## 139     1   148  176.6  27.2     Aix  6.37020  0.74098 0.09465728  2.193551172
## 140     0   156  166.6  27.4     Aix  6.43510  0.79639 0.09471008  2.622564932
## 141     1   123  142.4  30.2     Aix  7.13440  1.02557 0.10124228  2.842464537
## 142     1   149  244.1  33.3     Aix  5.70090  0.66104 0.08843076  2.277779974
## 143     0   120  227.0  23.9     Aix  3.46700  0.99079 0.11099550  2.833977758
## 144     0    77  121.2  25.9     Aix  8.10250 -0.41948 0.09638465  1.550112446
## 145     0   107   98.2  29.8     Aix 11.52560 -0.67474 0.06557439  1.370419012
## 146     0    83   98.5  30.5     Aix 12.16220 -0.78540 0.07867655  1.098612289
## 147     0   120  109.1  29.6     Aix 10.97860 -0.72740 0.06123724  1.282321771
## 148     1    96  159.1  27.6     Aix  7.00290  0.02856 0.07797435  1.362769816
## 149     1    98  143.7  27.8     Aix  6.18470  0.88848 0.09534149  2.636052821
## 150     0   102  144.5  27.9     Aix  6.34110  0.90837 0.10728467  2.755188208
## 151     0   144  253.4  29.1     Aix  5.67270  0.71054 0.09555103  2.888536742
## 152     0   103  151.7  30.3     Aix  6.81540  1.17939 0.09974969  2.219420852
## 153     0   113  150.3  31.4     Aix  7.02140  1.26706 0.10019980  2.039270377
## 154     0   115  207.2  30.5     Aix  5.82410  1.29250 0.11063453  2.074554620
## 155     1   117  122.0  29.0     Aix  7.65380 -0.50456 0.08372574  1.085527049
## 156     1    93  102.7  26.5     Aix  8.36480 -0.48503 0.06633250  1.154362304
## 157     0    93  132.0  29.8     Aix  6.25140  0.12832 0.06899275  1.205970807
## 158     0   100  149.8  23.9     Aix  5.03290 -0.36575 0.10597169  0.971914636
## 159     0    97  122.8  26.2     Aix 14.29480 -0.82498 0.08619745  1.137191771
## 160     0   101   98.4  26.2     Aix 14.17670 -0.85528 0.06542171  1.329194769
## 161     0    98   93.9  29.8     Aix 10.89040 -0.77241 0.06811755  1.273125663
## 162     1    83   98.9  30.0     Aix 10.40190 -0.90807 0.07197222  0.616266136
## 163     1    74   79.6  26.8     Aix 12.14000 -0.92565 0.07930952  0.731887009
## 164     0   118  103.7  27.0     Aix  5.59020 -0.17985 0.06033241  1.138473822
## 165     0   109  126.7  25.1     Aix  6.88190  0.95055 0.08197561  2.514869901
## 166     0    99  241.6  23.1     Aix  3.98250  0.49734 0.11747340  2.294351288
## 167     0    85  102.3  28.6     Aix  9.97650 -0.74995 0.06730527  1.150255522
## 168     1    92   78.5  28.6     Aix  9.44030 -0.63503 0.06949820  0.922272804
## 169     1    92  100.2  28.4     Aix  7.50070 -0.01333 0.07987490  0.956664626
## 170     0   109  135.6  26.4     Aix  6.44440  0.84029 0.07456541  2.559550193
## 171     0   117  128.4  27.2     Aix  6.62870  0.19740 0.09924717  1.700922603
## 172     1    91  118.1  24.1     Aix  7.14490  0.11220 0.07615773  0.957816479
## 173     1    69  131.4  19.6     Aix  6.50000 -0.53250 0.09497368  1.493578026
## 174     0    83  126.5  23.0     Aix 14.00140 -0.79550 0.09305912  1.344690811
## 175     0    71  103.9  25.9     Aix 10.68320 -0.75230 0.06797058  1.043451877
## 176     0   105  147.6  26.4     Aix  5.41202  0.28084 0.09093954  1.617406082
## 177     0   108  120.4  24.5     Aix  6.73573  0.71185 0.08324662  2.025645117
## 178     0    86  113.9  26.1     Aix  5.93633 -0.56931 0.08826098  1.621959193
## 179     1    26  187.3  21.7     Aix  4.12311  0.39852 0.10217632  3.008056023
## 180     1    79  149.8  24.0     Aix  2.69072 -0.73282 0.11072488  1.638025369
## 181     0   109  176.3  25.6     Aix  6.31981  0.07920 0.10430724  1.821641844
## 182     0   138  192.4  27.2     Aix  5.91692  0.53172 0.09638465  1.715777948
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## 183     0   126  153.9  27.4     Aix  5.63649  0.43984 0.08062258  2.315106374
## 184     0   100  132.1  25.6     Aix  6.30079  0.94317 0.10212737  2.750981968
## 185     0   133  183.6  28.8     Aix  5.45894  0.49642 0.09348797  2.722938814
## 186     1   112  157.0  28.4     Aix  5.76975  0.44814 0.09654015  2.074177712
## 187     1   110  130.5  27.6     Aix  5.59732  0.84860 0.09033272  2.455048636
## 188     0   104   90.2  21.2     Aix  9.80306 -0.32175 0.11371016  1.406832012
## 189     0    71   85.1  19.5     Aix  7.02140 -0.30373 0.11545562  1.510280341
## 190     0    86   92.6  19.9     Aix  2.96816  0.56931 0.11406139  2.908920877
## 191     1    84   66.9  21.0     Aix  2.30217 -1.52735 0.11657616  2.220615530
## 192     0    75   91.5  21.5     Aix  5.72713 -0.43241 0.08792042  1.508954374
## 193     0    96  118.6  21.2     Aix  4.68615  0.87606 0.10217632  2.406945108
## 194     0    87  116.8  24.6     Aix  5.73847 -0.39345 0.09959920  1.714338322
## 195     0   105  148.4  25.9     Aix  4.00125 -0.02499 0.09777525  2.234306252
## 196     0    60   75.8  17.9     Aix  2.77308 -0.44752 0.08938680  2.294048762
## 197     0   112  139.6  20.4     Aix  4.20476 -0.04758 0.08608136  2.094822644
## 198     0   117  154.7  20.4     Aix  3.80789  0.23861 0.08142481  3.437657879
## 199     1   105  152.6  20.4     Aix  2.65707  0.34556 0.09874209  2.912459354
## 200     1    46   67.2  15.0     Als  4.44072  0.62549 0.09889388 -0.345311185
## 201     1    92   82.7  18.0     Als  3.96232  0.17760 0.10271319 -0.209487225
## 202     0    68  100.1  15.8     Als  0.41231  0.24498 0.09654015  0.879626748
## 203     0    85   80.5  17.1     Als  3.61248  0.72664 0.10445095 -0.338273859
## 204     0    96   74.8  18.0     Als  5.21728  0.21243 0.09465728 -0.695149183
## 205     0   114   56.1  19.7     Als  1.97231  0.53172 0.09455157  0.062974799
## 206     0   127   72.2  21.5     Als  3.22490  1.05165 0.09974969  0.044016885
## 207     1   140  123.2  22.3     Als  5.66392  0.83536 0.09300538  2.630593037
## 208     1   131   98.0  23.6     Als  6.88186  0.95055 0.10064790  1.525186360
## 209     0    84  126.5  23.9     Als  1.52315  0.40489 0.11462984  1.092594216
## 210     0   126  211.7  26.0     Als  3.70135  0.67052 0.13111064  1.737303283
## 211     0   102   98.5  22.4     Als  3.16228  0.32175 0.12708265  0.270027137
## 212     0    75  118.5  19.8     Als  4.35660  1.01463 0.12231108  1.208064422
## 213     0    79   88.2  18.1     Als  5.99333  0.44872 0.11397368  0.073250462
## 214     1    99   81.8  20.5     Als  1.30384  0.56673 0.10816654  0.096218858
## 215     1    92  119.8  20.7     Als  2.88444  0.98279 0.10917875  0.341459778
## 216     0    70   69.4  17.6     Als  6.92315  0.18890 0.09391486 -0.567395975
## 217     0    70   66.7  19.4     Als  2.97321  0.34302 0.10917875 -0.420071260
## 218     0    73   58.4  22.3     Als  2.81780  0.47952 0.12202459  0.062035391
## 219     0    64   75.4  23.9     Als  6.60303 -0.03029 0.11849051 -0.081210055
## 220     0   120  103.9  27.1     Als  0.60000  0.00000 0.11827933  1.736246759
## 221     1    62   82.2  26.4     Als  3.02655  0.13255 0.14345731  0.098033740
## 222     1   101   74.1  26.2     Als  2.06155  0.88848 0.13133926  0.516410002
## 223     0   166  143.5  32.0     Als  1.69706  0.78540 0.13168143  2.160330045
## 224     0   239  133.5  34.7     Als  0.50000  0.92730 0.13805796  1.833221259
## 225     0   184  183.8  29.2     Als  4.38292  0.47385 0.14673105  1.392773327
## 226     0    87  100.1  25.2     Als  5.09215  0.34038 0.15732133  0.576613364
## 227     0   103  127.7  25.1     Als  1.14018 -1.30454 0.14774979  0.927428476
## 228     1   134   80.9  27.2     Als  1.48661  0.73782 0.13696715  0.431782416
## 229     1    98  105.0  27.8     Als  0.36056 -0.58800 0.13446189  1.156252068
## 230     0   124  113.8  23.3     Als  2.73130  0.41451 0.12198361  1.347813374
## 231     0   146  119.2  23.1     Als  3.52278  0.60375 0.10232302  1.343125866
## 232     0   154  100.2  26.6     Als  2.12132  0.78540 0.10830512  0.305276381
## 233     0   118   73.5  25.4     Als  5.96657  0.23685 0.09959920 -0.524248644
## 234     0    98   60.8  19.5     Als  5.29528 -0.18999 0.09859006 -0.322963887
## 235     1    95   48.8  18.6     Als  4.62277  0.89268 0.09586449 -0.941608540
## 236     1   110   80.8  21.4     Als  4.52217  0.31476 0.10435516 -0.353821875
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## 237     0   117   86.5  25.8     Als  4.08044  0.62880 0.10143964 -0.188742125
## 238     0    63   63.3  18.8     Als  6.22896  0.09647 0.11189281 -0.260066905
## 239     0    69   51.0  20.1     Als  8.62148  0.90874 0.12529964 -0.122167634
## 240     0    76   77.8  18.2     Als  5.09902  0.44611 0.11687600 -0.139262067
## 241     0   109  108.8  23.0     Als  0.31623 -0.32175 0.11072488  0.979828753
## 242     1    79   66.3  20.1     Als  3.45398  0.38588 0.12198361 -0.432322562
## 243     1    81   77.4  22.4     Als  1.45602  0.27830 0.11696153  0.202940844
## 244     0   127  126.3  29.1     Als  0.70000 -1.57079 0.11242775  1.206270163
## 245     0    79  159.2  30.1     Als  2.76586  0.86217 0.11730303  0.506817602
## 246     0    59   83.9  19.0     Als  5.37122  0.42201 0.11781341 -0.282362911
## 247     0    97   68.1  21.6     Als  2.60000 -0.39479 0.10798148 -0.391562203
## 248     0   132  193.6  25.0     Als  3.20156  0.25255 0.11691878  1.671661256
## 249     1    84  104.3  23.0     Als  0.94340  0.55860 0.11441154 -0.011060947
## 250     0    27  122.7  22.1     Als  2.14009  0.91795 0.14429137  1.008687581
## 251     0    31   84.2  18.0     Als  3.33766 -0.15037 0.13597794  0.234281296
## 252     0    69   59.1  19.4     Als  3.04138  0.47835 0.12066483  1.401675463
## 253     0   107   79.5  21.6     Als  3.36155  0.53022 0.10981803  1.309413317
## 254     1   135  116.7  27.6     Als  2.40832  0.84415 0.10124228  0.038258712
## 255     1    99   96.8  24.8     Als  7.21249  0.29544 0.09465728 -0.231932057
## 256     0   116   77.6  21.5     Als  3.70135  0.90027 0.10751744 -0.379797361
## 257     0   120   80.7  24.7     Als  4.52769  0.75416 0.11371016 -0.235722334
## 258     0    71  119.0  23.8     Als  6.08276  0.16515 0.11344602  0.035367144
## 259     0    91  139.3  21.8     Als  3.78550  0.21294 0.10648944  0.428530381
## 260     0    86  121.8  22.4     Als  2.37697  0.38832 0.11912179  0.466873736
## 261     1   126  125.1  25.7     Als  6.12209  0.90116 0.13049904  0.740507752
## 262     1   114  142.0  27.2     Als  5.72014  0.93429 0.12537942  0.966603546
## 263     0   139  159.2  29.1     Als  4.67547  0.72487 0.13126309  1.360976553
## 264     0   142  185.7  29.7     Als  4.24500  0.75208 0.13711309  1.376748948
## 265     0    92  115.6  24.2     Als  2.69072  0.73282 0.13575714  0.246078523
## 266     0   163   97.7  29.5     Als  3.78021  0.91671 0.11623253 -0.046043939
## 267     1   173  124.6  32.9     Als  3.05287  0.55165 0.12024974  0.131905071
## 268     1   169  153.2  35.0     Als  2.95466  0.41822 0.12405644  0.566449528
## 269     0   210  135.2  35.6     Als  4.26380  0.88507 0.11832160  0.131028262
## 270     0   226  125.7  36.2     Als  5.73149  0.74838 0.11379807 -0.306525160
## 271     0   206  132.6  34.4     Als  4.96488  0.97162 0.09848858  0.508021696
## 272     0   214  117.5  35.7     Als  4.03113  0.80294 0.09549869  0.552159487
## 273     0   161  140.6  36.3     Als  4.24500  0.81872 0.11747340 -0.236988958
## 274     1   185  137.4  36.4     Als  3.36155  1.04058 0.12676750  0.610308902
## 275     1   147  154.0  34.8     Als  3.64005  0.27830 0.11532563  0.990655814
## 276     0   208  125.9  33.2     Als  3.74833  0.76653 0.08426150  0.372941916
## 277     0   219  173.9  36.8     Als  2.19317 -1.14794 0.09949874  1.096610286
## 278     0   204  132.4  37.4     Als  4.92544 -0.10169 0.10867382 -0.360969868
## 279     0   157  138.6  29.5     Als  4.17732  0.19270 0.13243867  0.479953960
## 280     1   139   76.6  25.0     Als  5.10000  0.48996 0.10143964  0.263133200
## 281     1   156  128.6  27.0     Als  5.39073  0.86418 0.10812030  0.774727168
## 282     1   168  155.8  31.7     Als  4.00500  0.04996 0.12641202  1.084513364
## 283     0    98   83.5  24.4     Als  8.13941  0.18535 0.12727922 -0.051293294
## 284     0   114   90.5  27.2     Als  3.44819 -0.51555 0.11878552 -0.585190039
## 285     1   126   61.5  26.4     Als  3.53553  0.78540 0.08449852  1.070898450
## 286     0   113  112.4  27.7     Als  6.41950  0.31682 0.08532292  0.518793793
## 287     0    66   79.0  15.1     Als  6.13922  0.21337 0.08666026  0.335757696
## 288     1    60  102.4  14.6     Als  0.53852 -1.19029 0.09093954  0.731405893
## 289     1    79   78.0  12.6     Als  9.97246  0.27417 0.08769265  0.176471143
## 290     1    80   78.5  10.9     Als  6.08358  0.44159 0.07529940  0.402126207
```

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## 291     0    99   74.9  12.4     Als  3.60555  0.05550 0.07190271 -0.003004509
## 292     0    82   78.2  13.4     Als  1.43178  1.35970 0.06131884  0.154436353
## 293     0    92   82.6  13.9     Als  4.62277  0.89268 0.05744563  0.412109651
## 294     0    99   78.5  17.5     Als  8.45044  0.87757 0.06519202  0.428530381
## 295     1    69   82.4  14.8     Als  9.41116  0.82297 0.09899495  0.559615788
## 296     1    95   75.7  16.7     Als  2.92746 -0.13707 0.07000000  0.456791735
## 297     0    71   99.8  17.6     Als  4.50444  1.52638 0.07752419  0.893226792
## 298     0    74   78.2  14.2     Als  5.25547  1.20089 0.08573214  0.918288735
## 299     0    83   76.3  15.0     Als  3.58469  1.04473 0.06693280  0.427226600
## 300     0    92   94.8  17.2     Als  1.33417 -1.34400 0.07476630  0.792539924
## 301     0    99   64.0  22.7     Als  2.55539  0.53371 0.08848729  0.986189859
## 302     1    91   77.0  19.2     Als  2.86007  0.63651 0.10054850  0.721734637
## 303     1    79   56.4  16.1     Als  1.20830 -0.42663 0.09721111  0.882940752
## 304     0    58   55.6  14.5     Als  5.80517  0.73666 0.11519549  0.690142672
## 305     0   101   73.4  19.4     Als  2.26274  0.78540 0.09797959  0.352064331
## 306     0   100  106.0  24.5     Als  2.90689  1.50194 0.10168579  0.651282976
## 307     0   149  128.2  28.3     Als  1.91050 -1.46592 0.11510864  1.084851373
## 308     0   140  155.6  30.7     Als  2.56320  1.21203 0.12377399  0.788457360
## 309     1   141  115.1  31.1     Als  2.77849  1.04272 0.13262730  0.790273891
## 310     1   178  126.0  29.6     Als  3.71080  1.32582 0.13423859  0.458689869
## 311     0    54  103.2  19.6     Als  6.64078  0.32175 0.13122500  0.500775288
## 312     0   103   94.3  17.6     Als  1.62788  0.18535 0.09899495  0.458689869
## 313     0   129  100.4  23.2     Als  3.80789  1.16590 0.08191459  0.347835995
## 314     0   132  107.5  28.2     Als  4.46542  0.97658 0.08814760  0.746213901
## 315     1    81  100.3  19.7     Als  7.61577  0.52240 0.08637129  0.047837329
## 316     1    76  101.2  20.2     Als  6.67608  0.28859 0.07758866 -0.097612829
## 317     0    46   97.7  18.1     Als  6.30317  0.84152 0.09115920  0.609221946
## 318     0    80   81.8  17.5     Als  5.18941  1.13301 0.06140033 -0.119910297
## 319     0    91  101.3  17.9     Als  5.51543  1.18019 0.07449832  0.205386830
## 320     0   109  103.8  19.0     Als  1.40357 -0.07131 0.08402381  0.368801124
## 321     1    51   63.4  16.5     Als  1.02956  0.50710 0.08642916  0.873800680
## 322     1   101   78.4  18.9     Als  1.21655 -1.40565 0.07918333  0.574363645
## 323     0   121   85.9  21.9     Als  2.10238  0.44237 0.08264381 -0.088831214
## 324     0   132  114.8  24.6     Als  1.58114  0.96525 0.08683317  0.672434139
## 325     0    92  103.6  25.0     Als  2.60768 -0.07677 0.09300538  0.118671530
## 326     0    94   90.9  26.4     Als  3.50143 -0.02856 0.11004545 -0.006018072
## 327     1   124   94.3  26.2     Als  6.71193  1.07383 0.08449852  0.602127782
## 328     1   124   91.8  27.8     Als  7.64003  0.92468 0.08520563  0.233489843
## 329     0   162  146.4  30.9     Als  6.12944  1.07796 0.08826098  0.716863707
## 330     0   174  132.8  31.4     Als  3.55106  0.56457 0.09736529  0.807814256
## 331     0   164  134.0  29.3     Als  4.24382  0.60107 0.08826098  0.382537603
## 332     0   196  138.6  30.7     Als  4.87032  1.23606 0.09197826  0.459953293
## 333     0   179  141.8  32.6     Als  3.19061  1.00887 0.10411532  0.268499253
## 334     1    84  107.1  23.9     Als  4.81041  0.75599 0.11713240  0.418052224
## 335     1   156  143.8  27.3     Als  2.40416  0.78540 0.10449880  0.775187891
## 336     0   152  148.8  29.8     Als  1.30000 -1.17601 0.10295630  0.492254238
## 337     0   215  156.3  30.8     Als  4.51885  1.13684 0.10401923  0.947013905
## 338     0    78  113.8  27.6     Als  4.30116  0.30705 0.10936178  0.290428298
## 339     0    94   84.7  23.1     Als  5.02892  0.30288 0.10488088 -0.056570351
## 340     0    73   78.3  21.1     Als  6.23939  0.37753 0.09115920 -0.070422464
## 341     1    59   52.5  20.7     Als  3.11127  0.78540 0.11054411  0.455524308
## 342     1    99  157.4  25.9     Als  1.14018  0.90975 0.11081516  1.174028928
## 343     0    53  101.0  17.4     Als  8.15414  0.58460 0.10639549  0.408792898
## 344     0    44   71.5  19.8     Als  5.34509  0.30400 0.10435516  0.067658648
```

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## 345     0    48   89.1  16.7     Als  5.00400 -0.03998 0.09235800  0.414755155
## 346     0    63   88.4  17.0     Als  1.64012  0.65570 0.09439280  0.325700140
## 347     1   117  121.4  21.1     Als  5.00000  0.92730 0.09974969  0.564176799
## 348     1   109   93.5  24.3     Als  5.81808  1.14559 0.11882761  0.374318379
## 349     0    73  111.0  26.2     Als  6.17414  1.13613 0.09465728  0.349952398
## 350     0   131  105.2  26.3     Als  6.00000  0.92730 0.10261579  0.280657458
## 351     0   142  105.7  28.6     Als  5.73062  1.06031 0.09022195  0.346422567
## 352     1   181  126.0  29.9     Als  2.59615  1.29779 0.08746428  1.094938883
## 353     0   150  104.6  30.0     Als  4.03113  0.80294 0.10881176  0.827240915
## 354     1   128  107.8  25.6     Als  5.71402  0.99736 0.11958261  0.304539190
## 355     1   119  148.6  29.0     Als  4.11825  0.50710 0.08360622  0.587230955
## 356     0    98  133.9  28.5     Als  7.59539  0.15866 0.10000000  0.330022913
## 357     0    82   98.0  21.4     Als  6.77791  0.37777 0.09808160  0.368801124
## 358     0    60   86.0  23.2     Als  8.59593  0.51049 0.09444575  0.333611004
## 359     0    93   92.7  21.2     Als  6.62118  0.43663 0.10242070  0.227135573
## 360     0    36   85.1  21.6     Als  5.34509  0.30400 0.09954898 -0.103140759
## 361     1    94   95.5  22.3     Als  3.00167  0.52328 0.08312641 -0.294371061
## 362     1    70   81.5  22.9     Als  6.45368  0.86217 0.10324728  0.557327457
## 363     0    45   59.9  21.0     Als  7.35731  1.02805 0.10401923  0.747635366
## 364     0    82   71.7  23.5     Als  2.59422  0.48089 0.10719142  0.231111721
## 365     0   142  157.7  29.6     Als  0.14142  0.78540 0.11945711  1.525186360
## 366     0   131   82.2  30.0     Als  1.07703  0.38051 0.11480418  1.000631880
## 367     0   125  103.9  28.4     Als  4.70106  0.02127 0.10559356  0.308219724
## 368     1    65   89.1  23.3     Als  5.51453  0.07260 0.10237187 -0.202116184
## 369     1    87   80.4  22.7     Als  4.66476  0.54042 0.08848729 -0.208254939
## 370     0    96  101.4  23.8     Als  1.50333  1.50423 0.08972179  0.615726034
## 371     0    35   87.8  20.3     Als  4.60977  1.14596 0.09648834  0.423959691
## 372     0   103   95.1  23.3     Als  5.10392 -0.03920 0.08372574 -0.135819723
## 373     0    79   89.6  22.1     Als  2.81603 -0.10674 0.08561542 -0.185125484
## 374     0    88   76.6  22.8     Als  5.00000  0.92730 0.09612492  0.441475546
## 375     1    70   75.4  18.4     Als  4.07185  0.43069 0.08378544  0.176471143
## 376     1    72   59.5  15.2     Als  2.43516 -0.33474 0.09262829  0.219938420
## 377     0    64   50.6  19.0     Als  5.54437  0.68319 0.07867655 -0.478035801
## 378     0    90   74.5  21.0     Als  3.00167  0.52328 0.08613942 -0.032523192
## 379     0    66   78.8  21.4     Als  3.08058  1.34156 0.09077445  0.308219724
## 380     0    57   85.0  23.5     Als  4.12311  0.68232 0.10134101  0.266969031
## 381     1    92   76.9  21.9     Als  3.72022  0.63275 0.08966605  0.062035391
## 382     1    67   53.5  19.2     Als  6.72681  0.08931 0.09471008 -0.245900538
## 383     0   101  114.5  25.2     Als  6.26259  0.67225 0.09869144  0.879211724
## 384     0    98   60.2  23.0     Als  5.80086  0.01724 0.11657616  0.551583616
## 385     1    74   97.0  22.3     Als  1.11803 -0.46365 0.09586449  0.300104592
## 386     1    61   96.8  18.5     Als  3.12570  1.44247 0.11264990  1.003935242
## 387     0    91  107.7  22.2     Als  2.30000  0.00000 0.11202678  0.506215011
## 388     0    91   93.0  22.7     Als  3.22025  0.63108 0.10339246  0.253866724
## 389     0    78   87.7  21.7     Als  2.60768  0.07677 0.10285913  0.539413081
## 390     0    62   64.2  17.9     Als  6.02163  0.62025 0.10931606  0.748581887
## 391     0    68   93.5  19.6     Als  4.65296  0.49249 0.07273239  0.324255053
## 392     1    79   81.8  21.3     Als  2.25610  1.34732 0.08006248  0.226338442
## 393     1   103   96.7  23.4     Als  4.00000  0.92730 0.08228001  0.875051984
## 394     0   120  144.0  26.4     Als  5.06952  1.18663 0.09710819  1.048721519
## 395     0   126  151.1  28.7     Als  6.15549  0.81987 0.09731393  0.923861997
## 396     0   144  180.5  28.7     Als  2.69258  1.19029 0.09721111  1.632568330
## 397     0    93  109.3  28.3     Als  4.29535  0.21109 0.11260551  0.519388854
## 398     0   109   93.0  26.6     Als  1.98494  0.71409 0.10163661  1.169381360
```

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## 399     1    98  111.8  25.7     Als  4.78017  0.65187 0.10276186  0.595534352
## 400     1   102  128.7  27.2     Als  5.39073  0.70661 0.09659193  1.753018641
## 401     0   111  134.8  26.6     Als  2.20000  1.57079 0.08384510  1.747110718
## 402     0   126  119.8  26.4     Als  1.47648  0.49394 0.10601887  1.350667183
## 403     0   156  117.5  28.1     Als  4.10488  0.97604 0.10124228  0.649717623
## 404     0   110  139.6  29.0     Als  3.84708  1.08390 0.09828530  1.088561953
## 405     1    78  101.7  25.4     Als  3.27567  1.02514 0.10124228  0.607044482
## 406     1    33   91.3  19.7     Als  2.28254  1.06795 0.11318127  0.820660501
## 407     0    58   80.5  19.5     Als  2.41661  0.42663 0.10917875  0.859931998
## 408     0    41   67.7  21.2     Als  3.96232  0.82110 0.09848858  1.435798556
## 409     0    87  110.2  23.4     Als  5.69386  0.53440 0.09407444  0.810930216
## 410     0    42   96.7  23.5     Als  5.73062  0.51049 0.10094553  0.923861997
## 411     0    39   51.7  12.7     Als  4.20476  1.12842 0.09279009  1.846247655
## 412     1    65   59.8  14.9     Als  4.85489  1.00565 0.06957011  1.481149892
## 413     0    65   83.2  16.9     Als  2.24722  1.20682 0.07169379  1.622748926
## 414     0    78   82.9  19.3     Als  6.16117  0.94677 0.06848357  1.556248084
## 415     0    57  104.9  19.4     Als  4.51885  1.13684 0.08197561  1.649619702
## 416     0    79   69.3  20.5     Als  2.64008  0.91972 0.08414274  1.369656720
## 417     1   101  111.2  19.3     Als  4.15933  0.47440 0.08154753  0.968123881
## 418     0    23   65.1  18.3     Als  2.77849  0.52807 0.10516653  0.923861997
## 419     0    19   48.2  20.5     Als  3.58469  1.04473 0.08865664  2.051170660
## 420     0    41   63.4  18.2     Als  4.20119  0.66731 0.08093207  0.585005022
## 421     0    52   58.8  15.5     Als  6.26420  0.29146 0.09159694  1.070555691
## 422     1    84   81.3  22.3     Cad  9.36220 -0.40629 0.09507891 -0.242071561
## 423     1   103  100.5  20.7     Cad  9.43660 -0.17038 0.08648699 -0.019182819
## 424     0   100  115.1  17.9     Cad  9.40480 -0.14942 0.09033272 -0.209487225
## 425     0    96   95.0  19.7     Cad 10.93850 -0.24941 0.08520563 -0.297059234
## 426     0   115   93.8  24.3     Cad  9.77390 -0.34440 0.08426150 -0.238257189
## 427     0   114  117.5  24.9     Cad  7.65310 -0.11787 0.09534149  0.103458708
## 428     0   153  128.8  27.1     Cad  4.68720  0.58800 0.09679876  0.177309015
## 429     1   203  182.0  25.4     Cad  6.10740  0.69264 0.11291590  1.783727298
## 430     1   208  188.0  25.3     Cad  6.79560  0.57576 0.10881176  2.060513532
## 431     0   121  137.7  25.5     Cad  6.12210  0.66964 0.10681760  2.344973859
## 432     0   112  101.1  21.1     Cad  6.81180 -0.86854 0.13061393  0.143234168
## 433     0   114  129.3  17.7     Cad  2.92060  0.66405 0.12976903  1.304270526
## 434     0    56  146.4  14.3     Cad  5.21540  0.07677 0.12198361  1.094604267
## 435     0   103  115.4  19.0     Cad  8.54750  0.10549 0.10430724  0.653366311
## 436     1    84   78.7  15.3     Cad  1.61250 -1.05165 0.12437845 -0.174353387
## 437     1    72   88.4  20.4     Cad  8.13450 -0.36453 0.11467345 -0.274436846
## 438     0    92   85.3  23.0     Cad 11.06930 -0.39896 0.08306624 -0.157824085
## 439     0    77   89.2  25.2     Cad  9.24450 -0.27384 0.09602083 -0.048140375
## 440     0   178  192.3  26.9     Cad  7.61580  0.40489 0.10995454  1.754922579
## 441     0   114  126.2  29.4     Cad  7.74140 -0.10352 0.10816654  0.309688153
## 442     0   173  143.1  28.5     Cad  6.93540  0.43140 0.10990905  1.738007013
## 443     0   194  177.6  30.9     Cad  6.39060  0.35144 0.10049876  1.942188948
## 444     0   188  159.8  31.6     Cad  7.81090  0.32580 0.09423375  1.421902789
## 445     0   143  203.2  32.3     Cad  6.48850  0.49812 0.10639549  1.824226659
## 446     0   125  214.5  30.8     Cad  6.41330  0.18822 0.08561542  1.397481551
## 447     1   106  138.0  34.1     Cad  7.55050 -0.19999 0.10917875  0.106160196
## 448     1   114  157.8  32.9     Cad  7.18470  0.60731 0.12525973  1.247319609
## 449     0   112  144.1  31.7     Cad  7.76660 -0.20750 0.11891173  0.651282976
## 450     0   100  147.7  30.8     Cad  9.60470 -0.25255 0.10232302  0.530628251
## 451     0   166   48.3  27.0     Cad  3.19530 -1.21935 0.15365546  0.397432936
## 452     0   135  183.0  27.8     Cad  5.80520  0.73666 0.12095454  2.051941868
```

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## 453     0    73  104.1  26.6     Cad 11.92810 -0.60661 0.09439280  0.140631130
## 454     1   101  102.6  27.0     Cad  7.31100 -0.05474 0.08526429  0.026641931
## 455     1   117  108.0  26.1     Cad  5.47450  0.16515 0.10014989 -0.098715973
## 456     0   118  146.9  24.8     Cad  4.96590  1.13417 0.11691878  0.824175443
## 457     0    74  129.9  26.5     Cad  7.36820 -0.13614 0.10705139  0.297879897
## 458     0   108  148.6  24.4     Cad  7.57690  0.39276 0.13300376  1.870416602
## 459     0    64  100.2  26.6     Cad 11.07660 -0.11764 0.08944272  0.061095099
## 460     0   131  134.7  26.5     Cad  7.76980  0.55587 0.09679876  1.512706723
## 461     1    77  100.8  24.6     Cad  7.92020 -0.42976 0.10163661 -0.133531393
## 462     1    91  155.1  30.1     Cad  7.02140  0.18622 0.10733126  0.873800680
## 463     0   102  113.9  30.2     Cad  5.16620 -1.31643 0.10183320 -0.081210055
## 464     0   105  130.5  28.9     Cad  4.16170  0.95613 0.11040833  0.563607809
## 465     0    82  199.7  26.8     Cad  6.90650 -0.04345 0.11920570  1.043099579
## 466     0    80  106.5  29.1     Cad  8.36000 -0.11990 0.09607289  0.100749903
## 467     0    89  119.6  29.8     Cad  8.45930 -0.11849 0.09444575  0.138891999
## 468     1    70   73.9  25.5     Cad  9.03770 -0.43395 0.10358571 -0.807436327
## 469     0    94  137.6  20.3     Cad  6.40700 -0.04684 0.13787676  0.451712359
## 470     0    77  129.5  26.8     Cad  8.99440 -0.49846 0.12095454  0.470003629
## 471     0   114  112.9  29.4     Cad 10.30920 -0.31562 0.10812030 -0.142716302
## 472     0   157  163.3  28.8     Cad  7.71040 -0.16941 0.08860023  0.630207381
## 473     1   202  199.6  30.8     Cad  8.33850  0.09609 0.11054411  1.338416281
## 474     1   191  268.6  30.7     Cad  5.72800  0.28310 0.12165525  1.992248330
## 475     0   112  151.5  31.9     Cad  8.06230 -0.12435 0.08860023  0.666803205
## 476     0   189  179.9  30.5     Cad  7.00000  0.00000 0.11713240  0.880456279
## 477     0    81   86.1  28.5     Cad 12.83160 -0.71370 0.10237187 -0.565633860
## 478     0   101  104.1  28.0     Cad 10.68920 -0.47620 0.09787747  0.179818427
## 479     0   133  128.1  29.0     Cad  4.78850  0.50101 0.11049887  0.390013004
## 480     1   147  131.0  28.7     Cad  7.24980  0.42663 0.11891173  0.953586517
## 481     1   175  185.6  28.4     Cad  6.45140  0.33155 0.12389512  1.069526708
## 482     0   143  172.3  23.9     Cad  5.45890  0.49642 0.16592167  0.691145178
## 483     0   123  158.5  22.6     Cad  5.78710  0.17367 0.14785128  1.081126974
## 484     0   137  141.8  31.0     Cad  7.27800  0.22165 0.10319884  0.822419516
## 485     1   224  157.0  32.2     Cad  8.12710  0.32564 0.11140018  1.193316224
## 486     1   182  175.2  32.5     Cad  8.13200  0.28675 0.12505999  1.203572724
## 487     0   257  153.6  34.5     Cad  8.56150  0.24781 0.10198039  1.351444084
## 488     0   269  173.5  34.3     Cad  8.46940  0.40024 0.11772850  1.401675463
## 489     0   319  155.9  34.9     Cad  8.37440  0.20442 0.10686440  1.054312030
## 490     0   209  185.6  33.1     Cad  3.70140  0.02702 0.13784049  0.658038003
## 491     0   209  174.6  30.4     Cad  3.93950  0.41822 0.14638989  1.298555447
## 492     1   175  157.8  33.1     Cad  5.17880  0.17467 0.12473973  0.836381349
## 493     1   208  141.3  33.4     Cad  8.96940  0.38879 0.10344080  1.541587246
## 494     0   185  182.1  34.9     Cad  8.57960  0.36968 0.13479614  1.197854123
## 495     0   254  211.2  36.3     Cad  7.69680  0.42878 0.11606033  1.790258343
## 496     0   296  189.0  35.0     Cad  8.50880  0.41106 0.13122500  1.795585474
## 497     0   201  203.9  34.3     Cad  7.39260  0.40312 0.12477981  1.270322185
## 498     1   168  168.5  33.6     Cad  7.74660  0.19486 0.12645157  0.972671065
## 499     1   102  161.9  32.3     Cad  5.96820  0.54617 0.12942179  1.072952542
## 500     0   137  134.1  30.2     Cad  6.98930  0.33532 0.11666190  0.950498903
## 501     0   134  120.5  32.8     Cad  9.63380 -0.16686 0.10079683 -0.003004509
## 502     1   141  110.3  26.0     Cad  3.80790  1.04839 0.08252272  1.127523632
## 503     0   114  123.8  26.2     Cad  5.84210 -1.45069 0.06418723 -0.162518929
## 504     0    97   90.6  22.4     Cad  9.14170 -0.34597 0.05856620 -0.596020470
## 505     1   108  118.9  21.3     Cad  9.29570 -0.70163 0.06557439 -0.303811454
## 506     0    99  112.9  21.0     Cad  9.70820 -0.04121 0.05727128  0.177309015
```

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## 507     0   135  127.8  18.8     Cad  2.10240 -0.04758 0.08648699  0.330741562
## 508     0   118  122.2  21.5     Cad  5.80090  0.01724 0.06308724  0.634988266
## 509     0   130  131.0  20.6     Cad  8.64520 -0.71992 0.07395945  0.744790414
## 510     1   105   85.0  17.3     Cad  4.15930 -0.16910 0.10587729  0.904218151
## 511     1   113  111.9  19.3     Cad  6.40700 -0.04684 0.07993748  0.506215011
## 512     0   103   96.6  14.8     Cad  2.64760  0.18999 0.09914636  0.282920755
## 513     0    86  120.7  15.6     Cad  6.54370 -0.67713 0.10049876 -0.029428811
## 514     0    85   97.1  18.6     Cad  8.70920 -0.37624 0.08473488  0.238229189
## 515     0   113  132.6  23.1     Cad  6.50080 -0.01538 0.06663332  0.725130226
## 516     0   122  135.4  23.5     Cad  7.40000  0.33030 0.07874008  1.835457324
## 517     1   127  113.4  24.9     Cad  6.46610  0.55368 0.07266361  1.265820208
## 518     1   123  129.4  22.5     Cad  6.18470 -0.68232 0.07355270 -0.239527031
## 519     0    93  100.3  21.9     Cad 11.32170 -0.42809 0.08426150 -0.294371061
## 520     0   114  124.3  24.4     Cad  5.82150  0.08599 0.08602325  0.572673027
## 521     0   201  188.4  26.5     Cad  3.59030  0.22471 0.11558547  1.069869820
## 522     0   207  217.0  26.6     Cad  5.92110  0.08454 0.11523888  1.233725762
## 523     0   169  150.4  27.6     Cad  4.11830  0.50710 0.10363397  0.572673027
## 524     1   183  164.1  26.5     Cad  6.63700  0.10567 0.10416333  0.862467925
## 525     1   192  160.7  26.6     Cad  7.00930  0.24498 0.10435516  0.831168478
## 526     0   101  111.7  27.9     Cad  9.54620 -0.39801 0.11949895 -0.055512710
## 527     0   109  109.1  25.6     Cad  3.40590 -0.05876 0.10798148  0.476855104
## 528     0   156  127.4  23.5     Cad  2.74590  0.57790 0.11309288  0.356974899
## 529     0   200  128.9  24.5     Cad  2.73130  0.41451 0.10816654 -0.112049504
## 530     0   138  168.3  25.8     Cad  3.35410  1.39094 0.10014989  0.572673027
## 531     1   111  121.0  26.5     Cad  7.46320 -0.31328 0.06457554 -0.036663984
## 532     1    96  102.2  27.9     Cad  9.48680 -0.32175 0.06884766 -0.155484903
## 533     0    77  101.7  27.5     Cad  9.68970 -0.54219 0.07523297  0.008959741
## 534     0   108  132.9  20.6     Cad  7.88920  0.53172 0.08099383  1.168760049
## 535     0   125  108.1  21.9     Cad  6.51920  0.36057 0.06906519  0.487352268
## 536     0   168  127.9  21.0     Cad  7.50600 -0.03998 0.07028513  0.431132855
## 537     1   135  135.9  20.9     Cad  7.20140  0.44502 0.08018728  1.584735300
## 538     1   137  128.5  23.8     Cad  5.94640  0.83298 0.08637129  0.229523158
## 539     0   137  126.0  25.4     Cad  7.76660 -0.96851 0.08944272 -0.279713903
## 540     0   132  165.1  30.1     Cad  6.50690 -0.04612 0.08966605  0.239016900
## 541     1   181  157.5  30.6     Cad  6.57340  0.23022 0.10526158  0.361164849
## 542     0   148  152.8  27.6     Cad  2.20230 -0.88187 0.11049887  0.092579181
## 543     0   141  157.6  27.5     Cad  3.71210 -0.08090 0.11506520  0.674983210
## 544     0   127  161.7  30.0     Cad  4.91930  0.46365 0.10089599  0.727065399
## 545     1   125  157.5  30.3     Cad  7.21110  0.33929 0.09203260  1.072268313
## 546     1   220  187.1  33.0     Cad  6.94260  0.20305 0.08905055  1.346513491
## 547     0   163  198.8  33.4     Cad  7.22770  0.25169 0.08700575  2.255074110
## 548     0   125  152.2  32.8     Cad  8.98110  0.32879 0.09060905  1.570697084
## 549     0   110  153.0  28.5     Cad  7.32390  0.61073 0.10478550  1.127523632
## 550     0   114   94.2  28.3     Cad 10.47850 -0.23109 0.08093207 -0.226900600
## 551     0    78   79.3  26.1     Cad 11.38640 -0.80403 0.06877500 -0.353821875
## 552     1    97  154.5  29.7     Cad  6.89420  0.41822 0.08111720  1.047669810
## 553     1   132  184.1  31.2     Cad  5.15460  0.31562 0.10109402  1.125903149
## 554     0    92  142.9  24.8     Cad  6.77420  0.54295 0.11726039  1.195436473
## 555     0    75  106.2  26.9     Cad  9.89950 -0.14190 0.09186947 -0.010050336
## 556     0    83  103.0  26.5     Cad 10.13900 -0.25933 0.07489993 -0.117658043
## 557     1   111  122.2  24.4     Cad 10.08070 -0.18961 0.07443118 -0.019182819
## 558     1   101  128.9  24.7     Cad  1.23690  0.24498 0.08689074  0.081579987
## 559     0   123  134.4  29.9     Cad  5.09900  0.44611 0.08803408  0.178982656
## 560     0   150  171.5  28.4     Cad  7.10210  0.16978 0.08797727  0.774727168
```

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## 561     0   184  158.3  28.4     Cad  0.60830  1.40565 0.09386160  0.115112807
## 562     1   203  172.5  29.4     Cad  6.80070  0.34500 0.09396808  0.933737645
## 563     0   161  177.1  29.3     Cad  7.20900  0.41400 0.09115920  1.687324451
## 564     1   170  174.1  33.8     Cad  7.03850  0.39370 0.09889388  1.313454815
## 565     1   217  221.1  35.1     Cad  6.77200  0.28438 0.08729261  1.316944283
## 566     0   131  266.7  24.1     Cad  3.22490  0.51915 0.11640447  1.727220948
## 567     0    86  102.5  27.3     Cad  9.33010 -0.30480 0.09143304  0.120446153
## 568     0   114   95.1  31.5     Cad 10.03190 -0.41013 0.06935416  0.028587457
## 569     0    85  109.3  31.7     Cad 10.29420 -0.69598 0.08068457  0.103458708
## 570     0   123  107.6  31.0     Cad 10.18430 -0.34038 0.06767570 -0.019182819
## 571     1   108  150.1  27.9     Cad  8.10560  0.03702 0.06957011  0.491642804
## 572     1   136  154.7  30.0     Cad  6.75430  0.44378 0.09005554  1.247606841
## 573     0   163  157.2  30.0     Cad  7.02140  0.45728 0.10373042  1.033184483
## 574     0   183  249.9  31.4     Cad  7.33760  0.30451 0.09607289  1.461169896
## 575     0   136  136.3  32.8     Cad  4.76760  1.40220 0.09924717 -0.196014884
## 576     0   129  133.4  33.6     Cad  5.92370 -1.19029 0.09607289 -0.186329578
## 577     0   173  149.1  30.4     Cad  7.18470 -0.96349 0.10478550  0.351360849
## 578     1   120  109.9  29.6     Cad  8.63480 -0.23374 0.07791020 -0.113168698
## 579     1   103   96.4  27.0     Cad 10.29610 -0.19549 0.06099180 -0.176737179
## 580     0   107  144.3  30.4     Cad  7.02570  0.08551 0.07042727  0.598286900
## 581     0   110  126.4  23.2     Cad  2.54950  0.44611 0.11131038  0.029558802
## 582     0   102  116.4  29.3     Cad 10.70750 -0.96466 0.08443933  0.302324349
## 583     0   109  126.2  28.9     Cad 10.84670 -0.71363 0.07409453  0.511625304
## 584     0   112  102.3  32.5     Cad  7.03850 -0.39370 0.06935416  0.410120920
## 585     1    87   97.8  30.5     Cad 10.63010 -0.71883 0.06268971 -0.441610555
## 586     1    75   84.0  27.6     Cad 10.96040 -0.79185 0.07733046 -0.170788321
## 587     0   117  105.3  27.9     Cad  4.25440  0.41106 0.05338539  0.429181635
## 588     0   146  135.9  27.6     Cad  6.97780  0.44442 0.08056054  1.153100474
## 589     0   122  190.4  22.8     Cad  4.20480  0.44237 0.11903781  1.096944232
## 590     0    99  115.0  29.9     Cad  7.09370 -0.70557 0.07176350  0.103458708
## 591     1    95   67.1  29.0     Cad 10.33680 -0.21447 0.06841053 -0.539568093
## 592     1    89   98.3  28.9     Cad  9.91410 -0.15188 0.07674634  0.008959741
## 593     0   158  168.2  29.6     Cad  4.83840  0.31521 0.06913754  1.507183678
## 594     0   138  117.5  28.0     Cad  6.72680  0.08931 0.09181503  0.256965100
## 595     1    93  108.1  24.3     Cad  6.80660 -0.04409 0.07582875 -0.646263595
## 596     1    64  115.6  20.2     Cad  3.20160  0.25255 0.09994999  0.332177312
## 597     0    83  123.0  27.4     Cad  8.90220 -0.66597 0.08949860  0.377065634
## 598     0    96   91.9  26.6     Cad 10.24160 -0.45491 0.07224957 -0.420071260
## 599     0   129  153.9  27.3     Cad  6.11310  0.26482 0.09203260  0.661656513
## 600     0   128  142.0  26.6     Cad  7.17840  0.32616 0.08348653  1.474763009
## 601     0   100  104.1  27.2     Cad  6.79120 -0.23784 0.08983318  0.657001734
## 602     1    52  218.2  23.1     Cad  5.86690  0.51703 0.09757049  1.816126826
## 603     1    97  100.5  23.5     Cad  4.66480 -1.03038 0.10620734  0.070458464
## 604     0   132  154.3  28.3     Cad  2.23610  0.46365 0.09444575  0.810040932
## 605     0   177  214.0  29.8     Cad  5.51090  0.20095 0.09523655  1.285091856
## 606     0   175  198.2  29.3     Cad  7.10210  0.16978 0.08306624  1.948763218
## 607     0   152  134.8  28.3     Cad  6.14000  0.52925 0.09257429  1.544152446
## 608     0   214  212.2  31.1     Cad  5.24690  0.13381 0.09000000  1.992111932
## 609     1   209  175.0  30.4     Cad  7.04560  0.11379 0.09570789  1.470865263
## 610     1   164  141.4  29.4     Cad  6.00830  0.32175 0.08774964  1.305897424
## 611     0   110  137.6  24.0     Cad 11.22010 -0.63994 0.09268225  1.095942060
## 612     0   104  103.7  20.8     Cad  9.34770 -0.60284 0.11401754  0.438899884
## 613     0    73   91.9  19.0     Cad  6.50000 -0.53250 0.11349009  0.692146680
## 614     0   114   78.5  19.7     Cad  3.22020  0.44976 0.11247222  2.547020358
```

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## 615     1    87   81.0  21.6     Cad  2.18400 -1.29250 0.11260551 -0.278392026
## 616     0    84   97.0  21.7     Cad  4.42830  0.11315 0.09154234  0.546964670
## 617     0   112  119.1  22.8     Cad  3.16230  0.60554 0.09465728  1.264973826
## 618     0   103  124.6  24.7     Cad  4.56950  0.40489 0.09884331  0.703097511
## 619     0   113  125.3  26.2     Cad  5.02200  0.22083 0.09899495  0.955511445
## 620     0    74   55.5  18.3     Cad  2.02480  0.35299 0.09989995  0.613562701
## 621     0   119  127.6  20.5     Cad  4.10490  0.04874 0.08865664  0.824175443
## 622     0   146  144.9  21.0     Cad  4.98200  0.18165 0.08117881  2.445819261
## 623     1    93  159.2  20.2     Cad  3.03640  0.30092 0.09929753  2.185264450
## 624     1    96   65.8  14.7     Ram  6.66110  0.94531 0.09869144  0.285930539
## 625     1    92   77.8  13.6     Ram  7.85490  1.02164 0.11260551  0.221542270
## 626     0    92   91.1  12.9     Ram  4.18690  0.86994 0.11077003  0.417393679
## 627     0    69   72.2  14.5     Ram  7.22770  1.31911 0.11696153  0.744315467
## 628     0    89   81.3  14.9     Ram  4.39090  0.52480 0.10168579  0.421338457
## 629     0   110   98.6  18.4     Ram  3.93950  0.41822 0.10158740  0.614644952
## 630     0   132  114.8  20.6     Ram  2.72030  1.27230 0.09909591  1.546285097
## 631     1   138  166.3  26.5     Ram  4.78539  0.45430 0.09016651  2.500697975
## 632     1   131  169.3  27.4     Ram  1.70294 -1.51204 0.09939819  0.817133160
## 633     0   107  128.8  23.3     Ram  2.80713 -0.07131 0.11882761  0.591668012
## 634     0    97  116.7  18.5     Ram  2.69258  0.54679 0.12345039  0.966603546
## 635     0    63   65.8  13.2     Ram  9.10055  0.01099 0.12029131  2.634044788
## 636     0    92  106.6  17.6     Ram  4.61411  0.52183 0.10756393  0.594982932
## 637     0    96   91.5  15.6     Ram  5.71402  0.99736 0.10913295  0.639218839
## 638     1    86  110.1  17.4     Ram  4.30116  0.95055 0.10770330  0.726098281
## 639     1    73  105.3  16.0     Ram  7.00071  0.77530 0.10004999  0.433728573
## 640     0    85   68.6  16.1     Ram  6.02163  0.62025 0.10648944  0.257738196
## 641     0    93   67.0  19.4     Ram  6.58635  0.52480 0.09654015  0.028587457
## 642     0    51   83.3  19.4     Ram  6.35138  0.58364 0.11958261  0.582774123
## 643     0    59   76.4  21.7     Ram  5.40833  0.33929 0.12481987  0.432431556
## 644     0   100  117.4  27.5     Ram  4.03113 -1.44644 0.14120906  1.113500901
## 645     1    82  100.0  22.1     Ram  3.77359  0.55860 0.12124356  0.740507752
## 646     1    83  122.9  27.1     Ram  2.92062  0.90675 0.11610340  0.478095799
## 647     0   151  182.2  32.4     Ram  3.33017  0.84914 0.13634515  0.817133160
## 648     0    60   93.8  22.7     Ram  7.31095 -0.69824 0.12747549  0.720275848
## 649     0    98  144.9  21.7     Ram  3.49285  1.15839 0.11502174  2.400074714
## 650     0    76   97.5  21.3     Ram  3.55106 -0.56457 0.11987493  0.730442965
## 651     0   116  144.4  22.5     Ram  2.14709  0.48448 0.12304471  0.777028665
## 652     1    73  118.2  24.3     Ram  4.07922  0.19740 0.12577758  0.591668012
## 653     1   102  128.1  23.1     Ram  4.21900 -1.47584 0.10217632  1.176498827
## 654     0   115   98.0  22.3     Ram  5.33667 -1.34400 0.10014989  1.052568350
## 655     0   135  138.6  22.1     Ram  3.25576 -1.38545 0.09767292  0.852711750
## 656     0   124  144.7  24.4     Ram  3.93954 -1.15257 0.09782638  1.023888742
## 657     0    90   82.5  21.6     Ram  5.20096 -0.90807 0.10540398  0.680061941
## 658     0    94   66.5  18.6     Ram  5.24023 -0.83940 0.09813256  1.264691539
## 659     1   116   66.7  19.3     Ram  2.90000 -0.76101 0.09354143 -0.156653810
## 660     1    87   80.5  22.1     Ram  4.13038 -0.12135 0.09736529 -0.066139803
## 661     0    56   59.3  16.0     Ram  7.71038  0.81291 0.12621410  0.553310235
## 662     0   128   86.4  23.6     Ram  7.49533 -1.34200 0.11857487  0.681580544
## 663     0   105  104.7  22.6     Ram  4.39318 -1.36447 0.12243366  0.905027540
## 664     0   115  153.3  24.1     Ram  5.09902  1.12469 0.10630146  1.936581054
## 665     0   138  165.1  25.0     Ram  4.38292  0.96381 0.09808160  2.211784729
## 666     1   134  176.7  27.6     Ram  2.00000  0.92730 0.09813256  0.923861997
## 667     1    96   92.8  22.1     Ram  5.51543 -1.18019 0.10373042  0.423959691
## 668     0   113  131.0  23.2     Ram  3.66879 -1.26629 0.09481561  1.080787704
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## 669     0    73  100.0  25.8     Ram  4.72017 -0.63503 0.11614646  0.414094435
## 670     0    85   92.8  23.5     Ram  6.51920 -0.72027 0.09792855  0.242946179
## 671     0    73   93.3  20.4     Ram  3.75899 -0.49935 0.11558547  0.256965100
## 672     0    70  113.1  24.3     Ram  2.22036 -0.62549 0.12413702  0.624332865
## 673     1   140  208.6  28.8     Ram  3.20624 -0.06242 0.12589678  1.849556568
## 674     1   137  190.3  32.8     Ram  0.82462 -0.24498 0.12903488  0.740507752
## 675     0   174  209.6  31.1     Ram  2.74591 -0.18311 0.13560973  0.903813210
## 676     0    84  170.5  24.7     Ram  4.13401 -0.56116 0.12267844  0.712949808
## 677     0    85   91.7  20.1     Ram  4.43847  0.39306 0.11588788 -0.058688996
## 678     0   147  133.9  28.5     Ram  0.98489  0.41822 0.10862780  0.770571078
## 679     1   202  143.2  30.0     Ram  3.33766 -1.42042 0.12004166  1.176498827
## 680     1   228  170.2  33.2     Ram  3.40147  1.14660 0.12316655  2.072794499
## 681     0   164  172.9  35.8     Ram  3.98246  0.49734 0.11432410  2.468861953
## 682     0   228  195.7  37.4     Ram  5.40370  0.68052 0.12328828  2.141006897
## 683     0   280  221.6  38.0     Ram  4.95782  0.72832 0.11907981  2.218333541
## 684     0   227  153.5  35.7     Ram  6.77200 -1.28641 0.14035669  0.968883182
## 685     0   276  223.5  34.7     Ram  1.70294  0.86854 0.13917615  2.207284913
## 686     1   221  158.7  35.6     Ram  3.11448  0.83082 0.12259690  1.629044442
## 687     1   163  164.7  36.8     Ram  2.23607 -0.17985 0.10927031  0.973426923
## 688     0   155  162.6  36.6     Ram  4.70106 -1.54952 0.11636151  0.155292884
## 689     0   183  133.8  37.9     Ram  3.80789  0.23861 0.11593101 -0.119910297
## 690     0   169  128.6  33.0     Ram  5.60357  1.53510 0.12731850  0.749999992
## 691     0   175  193.3  29.4     Ram  2.78927  0.25367 0.11823705  2.933005444
## 692     1   140  114.2  24.3     Ram  3.00167  0.52328 0.11166915  3.134841829
## 693     1   169  132.9  27.1     Ram  4.20119  0.90349 0.10700467  2.138653401
## 694     1   146  137.0  27.0     Ram  2.97321 -0.34302 0.12864680  0.975314072
## 695     0   103  112.6  21.3     Ram  5.31507  0.20847 0.12946042  0.828551818
## 696     0    93   73.1  24.5     Ram  3.18277 -0.80762 0.11282730  0.160416721
## 697     1   100   87.4  23.6     Ram  6.00083  1.15934 0.09460444  0.850150929
## 698     0   103  103.0  21.2     Ram  2.90172  0.03447 0.10913295  0.126632651
## 699     0    79   87.8  12.3     Ram  4.59674 -0.77001 0.09060905  1.028189824
## 700     1    97   79.8  14.3     Ram  5.07740 -1.01011 0.07063993  0.914288729
## 701     1    99   74.8  14.4     Ram  8.68217 -0.57203 0.06855655  0.006975614
## 702     1    90   66.6  13.0     Ram  5.16140 -0.62025 0.07259477  0.471876874
## 703     0   105   74.2  12.8     Ram  2.65707 -1.22524 0.05630275  1.038508365
## 704     0    92   80.7  12.9     Ram  5.23927  1.15839 0.06008328  1.325482222
## 705     0    99   87.9  14.2     Ram  6.17738  0.50710 0.05924525  2.336889897
## 706     0   110   97.1  17.5     Ram  8.68850  0.20868 0.06819091  1.451613827
## 707     1    48   58.4  11.9     Ram  5.73149 -0.82242 0.08740709  1.498953179
## 708     1    96   96.1  15.2     Ram  3.15753  0.19118 0.08573214  3.345790374
## 709     0    83   86.7  15.8     Ram  3.70000 -1.57079 0.08124038  1.153416081
## 710     0    78   70.0  13.8     Ram  5.24690  1.43699 0.07000000  0.913085601
## 711     0    84  110.5  13.2     Ram  0.70000 -1.57079 0.06284903  2.412425559
## 712     0    84   76.4  16.0     Ram  5.60803  1.18698 0.08396428  0.510425544
## 713     0    78   85.5  20.1     Ram  5.68507  0.88507 0.08933085  0.527682741
## 714     1    75   74.9  17.6     Ram  6.95701  1.24905 0.09049862  0.157858085
## 715     1    80   64.0  15.7     Ram  6.21289  0.99172 0.08786353  0.324977857
## 716     0    89   70.0  13.6     Ram  4.83011  0.47291 0.10677078  0.296394013
## 717     0    95   86.5  16.5     Ram  5.80086  0.94453 0.09959920  0.357674444
## 718     0    98  132.2  23.5     Ram  3.18277 -0.76318 0.11661904  0.885831524
## 719     0   127  167.1  28.9     Ram  3.89487  0.50959 0.11229426  0.877134017
## 720     0   134  147.6  30.6     Ram  4.20119 -0.90349 0.13274035  0.704087121
## 721     1    77   86.6  24.0     Ram  4.11096 -0.07304 0.10765686  0.152721087
## 722     1    53   84.3  17.6     Ram  4.90918 -1.50965 0.11077003  1.101607798
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## 723     0    91   75.2  16.1     Ram  4.33820 -0.45334 0.10004999  0.161268148
## 724     0    88  112.5  16.7     Ram  1.70000 -1.08084 0.10844353  0.872965607
## 725     0    99  148.6  19.6     Ram  1.56525  0.46365 0.08324662  1.287026359
## 726     0   120  126.3  24.4     Ram  3.41321  1.48279 0.09715966  0.525911261
## 727     0    93  133.7  21.1     Ram  3.52278  0.11379 0.09828530  0.319180740
## 728     1    70   86.3  20.1     Ram  7.40608 -0.04052 0.07861298 -0.131248287
## 729     1    64   79.4  16.7     Ram  4.82597 -0.10379 0.07582875  0.093490343
## 730     0    46  102.3  16.4     Ram  2.40416 -1.27536 0.10109402  1.258176858
## 731     0    93   95.6  19.5     Ram  5.09902  0.72990 0.06496153  2.714032273
## 732     0   104  104.8  20.1     Ram  5.46443  0.96757 0.07348469  1.979206756
## 733     0   141  104.7  20.5     Ram  4.10000  1.34948 0.07874008  2.140536641
## 734     1    97   58.6  18.5     Ram  4.56180  1.11695 0.06457554  1.233725762
## 735     1   100  100.2  19.0     Ram  0.64031 -0.67474 0.07556454  2.570243014
## 736     0    90   84.4  19.8     Ram  2.19545 -1.04600 0.06340347  0.915890652
## 737     0    70  110.9  15.2     Ram  3.82099  0.82242 0.09439280  0.823736750
## 738     0    83  107.3  22.9     Ram  2.66833  0.22680 0.09038805  0.385262401
## 739     0    67  132.6  26.1     Ram  2.90689 -1.50194 0.11077003  1.253334234
## 740     1    95  124.7  28.2     Ram  5.89406  0.25732 0.10339246  2.095068798
## 741     1   142  129.2  29.7     Ram  3.74833  0.16076 0.08549854  2.194220068
## 742     0   134  185.3  31.1     Ram  3.46699 -0.99079 0.10004999  1.202371523
## 743     0   145  118.2  26.0     Ram  4.95782 -0.84248 0.08160882  1.232560261
## 744     0   201  209.3  28.7     Ram  1.52643  1.01914 0.09214120  1.887826938
## 745     0   143  165.2  27.8     Ram  3.34215  0.89138 0.13382825  1.017402233
## 746     1   118  147.4  25.0     Ram  4.41022 -0.99537 0.10825895  0.650239680
## 747     1   115  181.7  27.2     Ram  4.38634  0.81765 0.11584472  2.664725076
## 748     0   146  178.1  30.8     Ram  4.30465  0.04648 0.11000000  1.600397168
## 749     0    82  110.1  30.7     Ram  3.48281  0.88709 0.12502000  1.435798556
## 750     0    95  119.2  23.3     Ram  4.56508  0.50284 0.10686440  0.344298673
## 751     0    69   81.8  21.2     Ram  6.43817  0.81835 0.10266450  0.081579987
## 752     0    65   91.9  18.8     Ram  5.60357  0.03570 0.10173495  0.616805947
## 753     1    88  125.4  26.0     Ram  3.13847  0.53496 0.09348797  0.489193324
## 754     1    90  121.9  28.6     Ram  4.70425  1.52827 0.09586449  0.131028262
## 755     0    78   66.5  16.9     Ram  7.72334  0.07776 0.09005554  0.132781111
## 756     0    60   75.1  18.8     Ram  4.62709 -0.10827 0.09736529  0.269263487
## 757     0    65   74.2  18.3     Ram  8.06226 -0.40815 0.08740709  0.099845335
## 758     0    74  100.6  18.6     Ram  5.12250 -0.89606 0.08654479  0.588897159
## 759     1   102  133.7  19.3     Ram  4.78539  1.11649 0.09586449  1.288957128
## 760     1   125  130.3  24.4     Ram  5.86941  1.32995 0.09828530  0.932557704
## 761     0   134  124.3  26.1     Ram  6.23618  1.29470 0.09934787  1.026399955
## 762     0   129  141.2  26.6     Ram  4.97695  1.17910 0.09471008  1.304541859
## 763     0   171  144.1  26.6     Ram  4.60109 -1.54906 0.10014989  0.791180921
## 764     1   191  200.4  27.8     Ram  0.30000 -1.57079 0.09252027  1.247606841
## 765     0   158  185.0  30.5     Ram  4.29535 -1.13839 0.10940750  0.799756916
## 766     1   104  128.3  29.6     Ram  3.10644 -0.99172 0.08809086  1.040630006
## 767     1   167  168.4  29.0     Ram  2.60000  0.39479 0.08049845  2.539315918
## 768     0   103  110.5  19.1     Ram  5.10882  0.05876 0.10084642  0.405465108
## 769     0    75   82.6  19.6     Ram  6.66108 -0.13553 0.10246951  0.538246219
## 770     0    48   93.8  22.3     Ram  7.47061 -0.48760 0.10300485  0.491642804
## 771     0    81   90.0  24.2     Ram  6.38905 -0.69674 0.07529940  0.123985980
## 772     0   112  134.9  24.5     Ram  2.74591 -0.57790 0.08933085  0.670901572
## 773     1    83  151.1  22.0     Ram  1.87883 -0.43984 0.08876936  0.683096845
## 774     1    55  103.1  17.8     Ram  6.00333  1.53748 0.11000000  0.681580544
## 775     0    70   86.7  22.2     Ram  7.95550  0.25412 0.10334409  0.202940844
## 776     0    60  160.7  20.1     Ram  0.76158 -1.16590 0.11004545  1.964591700
```

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## 777     0    94  209.9  26.7     Ram  1.41421  0.14190 0.11541230  2.301784773
## 778     0    97   93.3  24.1     Ram  1.74642  1.15839 0.11768602  1.089571544
## 779     0    79   84.0  19.1     Ram  5.34883  0.36315 0.11022704  0.890767775
## 780     1    87   76.1  18.2     Ram  4.96488  0.16184 0.09741663 -0.035627178
## 781     1    63   75.3  18.5     Ram  4.10122  0.02439 0.10069757  0.423959691
## 782     0    66  108.4  18.1     Ram  2.19545 -1.04600 0.10237187  1.326013430
## 783     0   114  105.1  21.2     Ram  4.92443 -1.15257 0.10276186  1.092258815
## 784     0    68   85.5  23.1     Ram  6.04649 -0.59718 0.09843780  0.285178942
## 785     0    88   77.7  21.1     Ram  3.80132 -0.95360 0.08068457  0.336472237
## 786     0    38   75.3  22.5     Ram  6.50308  0.03076 0.09622889  0.207826847
## 787     1    84   74.5  20.2     Ram  4.89183 -0.71306 0.08087027  0.958967006
## 788     1    94   70.2  20.5     Ram  4.31856  1.47804 0.07409453  0.344298673
## 789     0    80   66.0  20.4     Ram  4.50444  1.52638 0.07816649  0.437609561
## 790     0    92  109.8  22.3     Ram  2.86531  1.06031 0.07918333  2.323367632
## 791     0    83  121.9  25.1     Ram  3.06105 -0.66964 0.08876936  0.312618558
## 792     0    73   63.3  23.9     Ram  6.08030 -0.63363 0.08360622 -0.084469157
## 793     1    77   73.0  23.5     Ram  4.30116  0.02325 0.07823043  0.178146185
## 794     1    66   63.6  18.3     Ram  8.96939 -0.53851 0.08865664  0.174793290
## 795     0   127  131.3  26.3     Ram  5.06360  0.15866 0.08276473  1.539659018
## 796     0    92  110.1  17.2     Ram  6.48845 -0.42918 0.10573552  0.572108852
## 797     1    55  107.8  18.2     Ram  4.99800 -1.22373 0.09354143  1.424312428
## 798     1    73   62.1  17.4     Ram  5.19711 -1.04688 0.10425929  2.027753433
## 799     0    81  100.2  22.2     Ram  9.32952 -0.54042 0.09497368  0.435023910
## 800     0    79   81.4  20.1     Ram  4.68722 -0.98279 0.08117881  1.637442109
## 801     0    97  114.7  20.9     Ram  5.64004  0.64705 0.07635444  0.478715570
## 802     0    84   83.9  19.9     Ram  7.71298  0.23554 0.09016651  0.479953960
## 803     0    71   86.5  19.5     Ram  4.33244  0.32905 0.07602631  0.380489122
## 804     1    91  112.2  21.7     Ram  0.53852  0.38051 0.07429670  0.606499374
## 805     1   110  140.7  23.9     Ram  1.65529  1.13417 0.07797435  2.461467418
## 806     0   119  169.0  26.4     Ram  1.64010  0.65570 0.08360622  3.056827373
## 807     0   167  162.7  29.2     Ram  3.80000  0.00000 0.08497058  1.918245267
## 808     0   131  168.6  31.2     Ram  4.60430  1.52735 0.09523655  1.058831419
## 809     0    93  134.1  25.2     Ram  1.16620  0.54042 0.09289779  0.780241887
## 810     0   115  119.2  25.3     Ram  3.85880  0.54486 0.09322017  2.895027569
## 811     1   128  122.4  28.3     Ram  4.60110  0.02174 0.09370165  1.892810713
## 812     0    63   89.1  22.2     Ram  1.50000  0.92730 0.11467345  3.060348917
## 813     0    83   93.3  21.0     Ram  1.88680 -0.55860 0.10747093  1.737831127
## 814     0   123  136.7  22.2     Ram  0.63250  1.24905 0.11198214  2.354703047
## 815     0   114  115.8  26.5     Ram  2.54950 -1.12469 0.09165151  0.595534352
## 816     0    83   92.9  25.5     Ram  3.94080 -0.62320 0.10440307  0.327863862
## 817     1    68   79.3  18.0     Ram  4.60650  0.47336 0.10049876  1.401675463
## 818     1    66   96.8  21.4     Ram  6.29360 -1.26412 0.10069757  1.205671361
## 819     0    78   72.5  20.5     Ram  6.39530  1.10016 0.11238327  2.686213506
## 820     0    96   86.2  23.1     Ram  2.81600 -1.28274 0.09279009  2.431593774
## 821     0   109  116.0  25.1     Ram  4.66150 -0.39644 0.08056054  0.587786665
## 822     0    55   82.5  25.1     Ram  4.82600  0.10379 0.09591663  0.659590397
## 823     0    56   60.9  14.6     Ram  5.37120  1.14879 0.08814760  2.158137189
## 824     1    74   59.0  13.6     Ram  6.22010  1.49033 0.08154753  1.019208266
## 825     0   123   91.3  17.7     Ram  2.45150  1.36540 0.07635444  2.139948510
## 826     0    96   91.2  20.5     Ram  2.54950  0.84090 0.07141428  3.793149375
## 827     0   118  117.1  20.9     Ram  2.40420 -0.29544 0.06640783  2.582713710
## 828     0   146  132.9  23.1     Ram  5.14000  0.92340 0.07700649  1.400443784
## 829     1    68   70.4  17.5     Ram  4.11100  0.32175 0.08809086  1.205671361
## 830     0    70   80.6  16.8     Ram  3.80790  1.33219 0.09055385  1.763359995
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## 831     0    61   80.5  20.9     Ram  4.96490  0.32812 0.07382412  1.075343662
## 832     0    67   46.4  15.4     Ram  4.27200  0.35877 0.08402381  1.362257783
## 833     0    78   53.9  16.0     Ram  5.10000 -0.48996 0.08276473  1.885705082
## 834     1    87  110.9  17.3     Pla 12.79140 -0.68573 0.09710819  0.582774123
## 835     1   108  127.3  15.3     Pla 11.23790 -0.20612 0.09311283  1.810744769
## 836     0    91  119.2  12.8     Pla 12.90660 -0.17916 0.09848858  0.350656872
## 837     0    98  114.5  14.3     Pla 13.50700 -0.47689 0.09460444  1.090580117
## 838     0   114  133.3  18.7     Pla 11.85960 -0.42593 0.09518403  1.247032294
## 839     0   133  147.1  18.9     Pla  7.76210 -0.26060 0.10821275  2.100836039
## 840     0   158  186.3  20.4     Pla  4.66900  0.75510 0.10163661  1.320955520
## 841     1   121  157.7  19.5     Pla  4.60980 -1.50567 0.09823441 -0.482886255
## 842     1   103  131.4  18.4     Pla  4.56180  0.45384 0.10751744 -0.225646682
## 843     0   126  131.7  18.7     Pla  5.07740  1.01011 0.10310189 -1.171182982
## 844     0   118  125.2  17.7     Pla 11.20040 -0.65243 0.11614646 -0.103140759
## 845     0   103  129.7  13.9     Pla  4.44180  1.02652 0.11743083 -0.896488105
## 846     0    78  133.7  10.4     Pla  8.05050 -0.11203 0.11282730  0.701115350
## 847     0   104  104.8  13.2     Pla  9.67470  0.12435 0.09602083  0.809150856
## 848     1   105  123.6  11.6     Pla  3.80130  1.10715 0.12091319  0.332894415
## 849     0    80  100.4  19.8     Pla 11.98540 -0.70863 0.09787747  0.463104888
## 850     0   125  127.4  18.7     Pla  4.12310  0.68232 0.12267844 -0.142716302
## 851     0   161  114.1  21.9     Pla  6.71190  0.05963 0.11683321  0.179818427
## 852     0   130  121.3  21.3     Pla  4.03110  0.80294 0.11300442 -0.468404908
## 853     1   119  117.5  21.1     Pla  4.52770  0.53284 0.10530907 -0.384192973
## 854     1   129  131.3  22.1     Pla  4.01620  0.32962 0.09792855 -0.176737179
## 855     0   168  147.1  22.6     Pla  2.00000  0.92730 0.11207141 -1.032824548
## 856     0   237  140.0  24.0     Pla  3.84710  0.48690 0.10232302  0.028587457
## 857     0   146  160.2  24.5     Pla  3.51140  1.22203 0.11081516 -0.369615455
## 858     0   150  154.8  23.8     Pla  3.36150  0.39708 0.09679876 -0.430782916
## 859     0   119  132.4  23.4     Pla  4.63250  0.57004 0.08613942 -0.156653810
## 860     1   227  148.7  26.3     Pla  6.07450  0.35299 0.12288206  0.081579987
## 861     1   172  143.8  25.1     Pla  3.98250  1.07345 0.12692517 -0.596020470
## 862     0   219  243.0  25.7     Pla  6.80660  0.17723 0.11224972  1.824710569
## 863     0   142  152.1  25.8     Pla 12.38470 -0.67096 0.09481561  0.851005265
## 864     0   157  236.9  24.0     Pla  5.24790  1.03038 0.12206556  0.933344486
## 865     0   136  127.5  21.2     Pla  5.12250  0.89606 0.11691878 -0.796287939
## 866     0   113  117.4  21.0     Pla 18.41140 -0.83919 0.09486833 -0.360969868
## 867     1   151  134.9  22.2     Pla  8.33550 -0.52807 0.08642916  1.616612116
## 868     1   147  151.0  19.5     Pla  5.99420  0.48603 0.10784248  1.003202104
## 869     0   128  129.3  18.9     Pla  4.31050  1.50114 0.11541230 -0.423120043
## 870     0   111  165.0  21.8     Pla  8.20790 -0.38729 0.11282730  1.901958262
## 871     0   111  127.6  17.3     Pla  6.82640  0.55549 0.13627179 -0.648173815
## 872     0   100  106.0  20.8     Pla 15.22010 -0.64087 0.08549854  0.160416721
## 873     0   133  108.9  19.6     Pla  5.80520  0.83414 0.10074721  0.461215123
## 874     1    99  108.6  19.8     Pla  9.94640 -0.22303 0.11264990  1.435560602
## 875     1   132  165.7  21.6     Pla  4.92440  1.06173 0.11077003  0.592221262
## 876     0   128  129.8  22.6     Pla  6.50000 -1.17601 0.10549882  0.370873663
## 877     0   142  117.7  22.1     Pla  5.30090 -1.55193 0.11157957 -0.466808738
## 878     0   127  192.9  21.7     Pla  7.35530 -0.12267 0.12810152  1.629828602
## 879     0   127  141.6  24.4     Pla  8.86000 -0.28605 0.10606602  1.722230740
## 880     0   169  157.8  25.3     Pla  9.35360 -0.10712 0.10663020  1.694146640
## 881     1   102   92.3  20.9     Pla 11.47390 -0.52996 0.10616026  0.220740667
## 882     0   124  197.7  16.3     Pla  7.55840 -0.45181 0.13408952  1.208661794
## 883     0   106  153.6  20.6     Pla 14.14850 -0.81539 0.12280065  0.039220713
## 884     0   134  128.7  24.3     Pla 14.44020 -0.63796 0.10411532  0.347129531
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## 885     0   151  166.0  22.3     Pla  7.78850  0.27301 0.10788883  0.728514324
## 886     1   158  143.6  23.4     Pla  6.86590  0.22025 0.10798148 -0.311974765
## 887     1   126  168.9  22.8     Pla  3.49860  1.03038 0.12353137 -0.282362911
## 888     0   130  200.6  27.2     Pla  7.85490 -0.54915 0.09648834  2.008884948
## 889     0   170  209.0  24.1     Pla  5.27730  0.17138 0.12549900  1.635690284
## 890     0    83   84.8  23.1     Pla 19.89100 -0.83163 0.10908712 -0.823255866
## 891     0   112  118.5  21.8     Pla 16.97290 -0.76873 0.10079683 -0.279713903
## 892     0   140  159.4  20.7     Pla  4.94060  0.94349 0.13095801 -0.020202707
## 893     1   121  100.4  21.6     Pla  5.75670  1.27102 0.12140840 -0.807436327
## 894     1   125  145.3  21.6     Pla  4.31390  0.76901 0.12533954  0.236651901
## 895     0   182  190.4  19.6     Pla  5.05670  0.42826 0.14673105  0.457424847
## 896     0   112  150.3  20.9     Pla  7.56640 -0.13255 0.12821856  1.572566438
## 897     0   153  119.7  24.1     Pla  6.03740  0.46365 0.10363397  0.318453731
## 898     1   150  109.1  25.4     Pla  5.38520  1.02401 0.11653326 -1.354795694
## 899     1   174  127.8  25.8     Pla  5.51540  0.39061 0.11832160  0.163818085
## 900     0   172  126.5  27.6     Pla  5.55430  0.40726 0.10644247 -0.046043939
## 901     0   166  157.2  27.5     Pla  4.92440  1.06173 0.11962441 -0.294371061
## 902     0   183  141.5  27.8     Pla  7.33350  0.09560 0.10658330  0.167207919
## 903     0   157  146.6  27.5     Pla  4.88770  0.53691 0.13401492  0.445967051
## 904     0   198  137.5  27.0     Pla  4.78020  0.91893 0.12605554 -0.404965233
## 905     1   184  121.4  27.3     Pla  5.44240  0.35662 0.12684636 -0.060812139
## 906     1   162  122.4  26.9     Pla  6.86220  0.32636 0.11349009 -0.761426021
## 907     0   164  168.4  27.6     Pla  7.55050  0.19999 0.12957623 -0.081210055
## 908     0   162  174.3  28.7     Pla  5.91690  0.53172 0.13026895  0.137149838
## 909     0   175  161.0  27.6     Pla  6.90800  0.38588 0.13693064 -0.153151179
## 910     0   228  166.0  27.3     Pla  6.70670  0.04475 0.13505554 -0.162518929
## 911     1   202  181.2  27.0     Pla  6.28170  0.24112 0.12980755  0.944683806
## 912     1   146  135.1  24.8     Pla  6.10080  1.55440 0.12275993 -0.742337425
## 913     1    95  129.0  23.4     Pla  5.90080  1.55385 0.14408331 -1.142564176
## 914     0   115  112.5  24.1     Pla  5.98080  0.35877 0.12012493  0.640273691
## 915     0   141  144.7  26.4     Pla 10.18330 -0.12801 0.13187115  1.259880436
## 916     1   166  173.5  18.2     Pla  5.77060 -1.08390 0.08093207 -1.114741671
## 917     0   128  165.0  18.8     Pla  7.40950 -1.01649 0.07252586  0.457424847
## 918     0   103  123.5  17.1     Pla 12.20370 -0.58118 0.06324555  1.125254220
## 919     1   106  151.3  14.7     Pla 15.58780 -0.72185 0.07362065 -0.062939800
## 920     0   114  144.5  15.9     Pla 10.37880 -0.43779 0.06074537  1.959953929
## 921     0   113  166.0  14.4     Pla  1.96470  0.25732 0.08306624  3.060958058
## 922     0   114  169.9  18.2     Pla  5.50090 -0.01818 0.06503845  1.856454228
## 923     0   128  162.4  16.3     Pla 11.83090 -0.39934 0.07758866  0.381855242
## 924     1   103  158.4  13.8     Pla  7.76980 -0.55587 0.10193135  1.427916036
## 925     1   119  139.4  15.0     Pla  7.64200  0.10488 0.07791020  0.783444819
## 926     0   108  131.8  11.5     Pla  3.80790  0.52240 0.09252027 -0.041864204
## 927     0   101  143.8  12.4     Pla  7.16940 -0.52607 0.09412757  0.006975614
## 928     0    96  131.9  11.8     Pla 17.68670 -0.75341 0.07628892  0.099845335
## 929     0   134  178.4  18.5     Pla  7.41080 -0.05400 0.07042727  1.901659665
## 930     0   142  160.6  17.1     Pla  5.94640  0.73782 0.07874008 -0.497580397
## 931     1   125  148.5  17.2     Pla  6.10740  1.52166 0.07259477 -0.916290732
## 932     1   125  164.4  17.0     Pla  7.70060 -0.65649 0.07726578  0.599385801
## 933     0   103  128.5  16.4     Pla 16.82410 -0.69702 0.07402702 -0.054456186
## 934     0   132  172.6  20.1     Pla  7.34980 -0.26148 0.08854377  1.859573869
## 935     0   140  197.8  20.8     Pla  4.97690 -1.17910 0.10344080  0.549854011
## 936     0   148  196.0  21.6     Pla  3.80130  1.54449 0.10377861  0.648149815
## 937     0   174  175.6  21.7     Pla  4.90310 -1.36540 0.09628084  0.237440856
## 938     1   183  186.2  20.8     Pla  5.06950  0.25933 0.09565563  0.426574071
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## 939     1   134  177.8  21.9     Pla  4.03610  0.83798 0.10084642  0.141499562
## 940     0   109  157.3  23.9     Pla 12.44030 -0.63707 0.12445883  0.514020515
## 941     0   135  178.0  21.2     Pla  5.32260 -1.12395 0.10416333  0.746213901
## 942     0   150  200.1  18.9     Pla  2.40000  0.00000 0.10844353 -0.001000500
## 943     0   152  184.6  18.2     Pla  2.98330  0.88035 0.11273864 -0.243346259
## 944     0   146  211.4  21.8     Pla  3.86010 -0.63832 0.10373042  0.453620150
## 945     1   125  183.7  22.4     Pla 10.70050 -0.65285 0.06715653  1.224363494
## 946     1   106  127.0  21.7     Pla 14.79220 -0.74236 0.06196773  0.209450224
## 947     0    73  126.1  21.5     Pla 16.42680 -0.83708 0.07503333 -0.141563564
## 948     0   112  134.8  14.6     Pla  5.58660  0.77274 0.08348653  0.116003676
## 949     0   141  198.4  15.8     Pla  7.01780  0.57219 0.08167007  0.968123881
## 950     0   130  143.2  14.5     Pla  6.64830  0.36933 0.07842194  0.107957142
## 951     1   101  158.8  15.2     Pla  6.57650  0.79615 0.08988882 -0.334075112
## 952     1   110  159.2  16.2     Pla  6.81540 -1.31870 0.08324662 -1.030019497
## 953     0   117  160.3  18.6     Pla  8.34870 -0.81928 0.09305912  0.426574071
## 954     0   123  202.0  21.7     Pla  8.59130 -0.69474 0.08826098  1.383540573
## 955     0   142  179.4  22.8     Pla  7.04560  0.60375 0.09203260  0.923464936
## 956     0   164  252.1  23.0     Pla  4.96490  0.48166 0.09899495  0.803793701
## 957     1   155  195.9  23.6     Pla  4.52220  0.31476 0.09899495  0.544066958
## 958     0   129  197.4  24.0     Pla  1.08170 -0.98279 0.11256109 -0.616186139
## 959     0   125  195.7  24.1     Pla  3.44090  0.95055 0.10807405  0.193096630
## 960     0   133  197.4  23.2     Pla  2.40420 -1.27536 0.11789826  0.164666622
## 961     0   116  180.8  23.3     Pla  3.67970  0.74696 0.10473777  0.204572166
## 962     0   105  167.7  22.8     Pla  5.72800  1.28770 0.10502381 -0.881889305
## 963     1   112  164.1  23.3     Pla  5.18650  0.97745 0.09731393 -0.869884359
## 964     1   104  172.8  25.0     Pla  4.77070  0.99442 0.09359487 -0.465215113
## 965     0   114  146.7  25.9     Pla  5.79400  0.37089 0.09016651 -0.397496938
## 966     0   165  145.4  26.0     Pla  6.09590  0.71574 0.09311283 -0.578034373
## 967     0    76  156.5  22.6     Pla  5.38520  0.54679 0.10981803  0.377065634
## 968     0   125  117.3  21.6     Pla 11.87140 -0.10973 0.09762172  0.383900930
## 969     0    95   98.2  21.1     Pla 19.33490 -0.88798 0.07113368 -0.343899752
## 970     1   137  126.6  22.8     Pla  5.59020  0.74744 0.07893035 -0.008032172
## 971     1   105  191.3  23.7     Pla  3.99620  1.01750 0.10373042  0.782987885
## 972     0    78  150.9  20.1     Pla  4.34170  0.50486 0.11233877  0.130150684
## 973     0    66  116.2  20.9     Pla 12.05400 -0.24297 0.09838699  0.422649933
## 974     0    92  153.1  21.4     Pla 12.13140 -0.50790 0.08049845  1.121351776
## 975     1   114  166.7  19.6     Pla 12.03040 -0.45621 0.08215838  0.893636041
## 976     1    65  170.5  20.6     Pla  4.97690 -0.39170 0.09088454  0.452984624
## 977     0   141  193.8  23.6     Pla  3.92050  0.65881 0.08955445  0.648672690
## 978     0   169  205.4  22.4     Pla  6.97210  0.14393 0.08797727  0.734289124
## 979     0   143  189.7  21.0     Pla  3.14010  0.64987 0.11549892 -0.455706325
## 980     1   132  182.9  21.9     Pla  5.59730  0.72219 0.09570789 -0.091019398
## 981     0   144  171.6  22.4     Pla  5.72800  0.77305 0.09412757 -0.843970070
## 982     1   125  180.2  24.4     Pla  5.68590  0.97304 0.09954898 -0.623621118
## 983     1   142  284.7  28.5     Pla  4.14000  0.64833 0.08538150  0.825052251
## 984     0   104  206.4  20.6     Pla  3.19530  0.35144 0.10876580  0.494086300
## 985     0    84  127.1  22.2     Pla 14.04170 -0.65917 0.09219544  0.721248611
## 986     0   118  118.2  25.8     Pla 16.23730 -0.71130 0.06188699  0.572108852
## 987     0    84  108.8  26.4     Pla 17.02940 -0.86854 0.07842194 -0.251028755
## 988     0   129  132.1  25.5     Pla 14.92410 -0.76171 0.05932959  0.354171814
## 989     1   113  208.9  22.2     Pla  9.01390 -0.05550 0.08549854  1.758547335
## 990     1    79  168.8  22.4     Pla  5.32540  0.97238 0.09767292 -0.850971266
## 991     0   102  161.3  22.7     Pla  5.32350  1.47674 0.10945319 -0.470003629
## 992     0   104  163.3  24.1     Pla  4.30120  0.95055 0.09628084 -1.272965676
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## 993     0   117  162.9  25.0     Pla  6.18470 -1.17227 0.09909591 -0.112049504
## 994     0   117  165.3  25.7     Pla  7.03280 -1.04989 0.09924717  0.211070970
## 995     0   110  179.1  25.3     Pla  7.16940 -1.04473 0.10981803  0.832909123
## 996     1   114  160.5  24.9     Pla 10.46520 -0.45510 0.08774964  1.225832139
## 997     1   111  137.1  22.2     Pla 11.81190 -0.49394 0.06877500  1.335264190
## 998     0   103  180.7  24.6     Pla  7.33480  0.19205 0.07778175  1.539659018
## 999     0   107  173.8  20.2     Pla  5.04480  0.24017 0.10261579  0.442760893
## 1000    0   105  142.3  22.7     Pla 17.32340 -0.87532 0.08916277  0.039220713
## 1001    0   106  138.4  22.8     Pla 17.60110 -0.93866 0.07007139  0.046883586
## 1002    0   128  122.7  25.8     Pla  7.80000 -0.39479 0.06819091  1.205072200
## 1003    1    93  120.0  25.9     Pla 16.71080 -0.89138 0.07127412 -0.369615455
## 1004    1    77   91.3  22.6     Pla 19.10240 -0.91159 0.08037413 -0.466808738
## 1005    0   104  146.0  19.1     Pla  6.45600  1.28824 0.10492855  0.141499562
## 1006    0   112  130.5  19.8     Pla  6.59240  1.40315 0.08573214 -0.514164525
## 1007    0   121  200.2  18.3     Pla  4.11830 -0.50710 0.11291590  0.147557564
## 1008    0   105  123.0  24.7     Pla 13.15220 -0.78540 0.06789698 -0.074723546
## 1009    1    96  106.2  23.9     Pla 12.56700 -0.47076 0.07569676  0.556754556
## 1010    1    94  107.1  22.8     Pla 11.54470 -0.24498 0.08396428  0.608133806
## 1011    0    98  139.9  21.6     Pla  5.70790 -1.51821 0.07422937 -0.282362911
## 1012    0   111  152.3  21.9     Pla  7.50600 -0.03998 0.10178409  1.518199432
## 1013    1    73  123.5  18.6     Pla  8.00000  0.00000 0.07899367  1.436749805
## 1014    1    78  159.1  16.1     Pla  6.38200 -0.61843 0.09165151  1.069183478
## 1015    0    83  145.3  19.5     Pla 17.36580 -0.85467 0.09386160 -0.093212382
## 1016    0    73  119.2  21.8     Pla 16.12760 -0.75909 0.06745369 -0.410980289
## 1017    0   115  174.6  20.3     Pla  5.53620  0.35031 0.09633276  1.153100474
## 1018    0   100  119.8  19.4     Pla  6.50000  0.39479 0.08221922 -0.420071260
## 1019    0    89  149.4  22.6     Pla  7.93100 -0.40158 0.08949860  1.670721141
## 1020    1    70  148.0  18.8     Pla  3.00170  0.03332 0.09560335  1.421420163
## 1021    1   104  123.0  18.1     Pla  2.47390 -0.24498 0.11653326 -0.342490309
## 1022    0   122  208.4  21.2     Pla  3.02650  0.13255 0.10540398  1.141033005
## 1023    0   119  208.3  22.6     Pla  3.47850  1.24905 0.10464225  0.983201437
## 1024    0   110  159.9  22.9     Pla  4.52770  0.53284 0.08288546  0.682086233
## 1025    0    94  131.2  20.8     Pla  5.37590  0.75909 0.09944848 -0.583396317
## 1026    0   104  195.2  23.7     Pla  3.75900  0.49935 0.09823441  0.470003629
## 1027    1   100  175.6  23.7     Pla  4.90310  0.20540 0.09741663  0.369492448
## 1028    1    90  140.5  22.3     Pla  4.98200  0.89919 0.09060905 -0.879476759
## 1029    0    89  162.6  19.2     Pla 16.66520 -0.32365 0.09772410  0.515215972
## 1030    0    77  103.7  17.1     Pla 16.67600 -0.28571 0.11224972 -0.314710745
## 1031    0    68  106.7  16.6     Pla 17.23080 -0.42471 0.11148991 -0.088831214
## 1032    0    65  123.0  16.3     Pla  3.79470  0.32175 0.10774971 -0.279713903
## 1033    1    77  130.3  17.3     Pla  5.77060 -1.41419 0.11428036 -0.205794913
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## 1036    0    93  177.3  20.4     Pla  5.99080 -0.58337 0.09633276  1.681758574
## 1037    0   116  233.6  22.1     Pla  4.80520 -0.20964 0.10237187  1.577534363
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## 1040    0   121  191.7  16.4     Pla  3.80000  0.00000 0.08497058  0.742413422
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```

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```

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```

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```

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## 952  -2.780620894    FALSE
## 953  -1.358679194    FALSE
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## 973  -1.111697528    FALSE
## 974  -0.574475651    FALSE
## 975  -0.906340401    FALSE
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```

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## 998  -0.396009949    FALSE
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## 1000 -1.714798428    FALSE
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## 1039 -0.059750004    FALSE
## 1040 -1.614450454    FALSE
## 1041 -1.599487582    FALSE
```

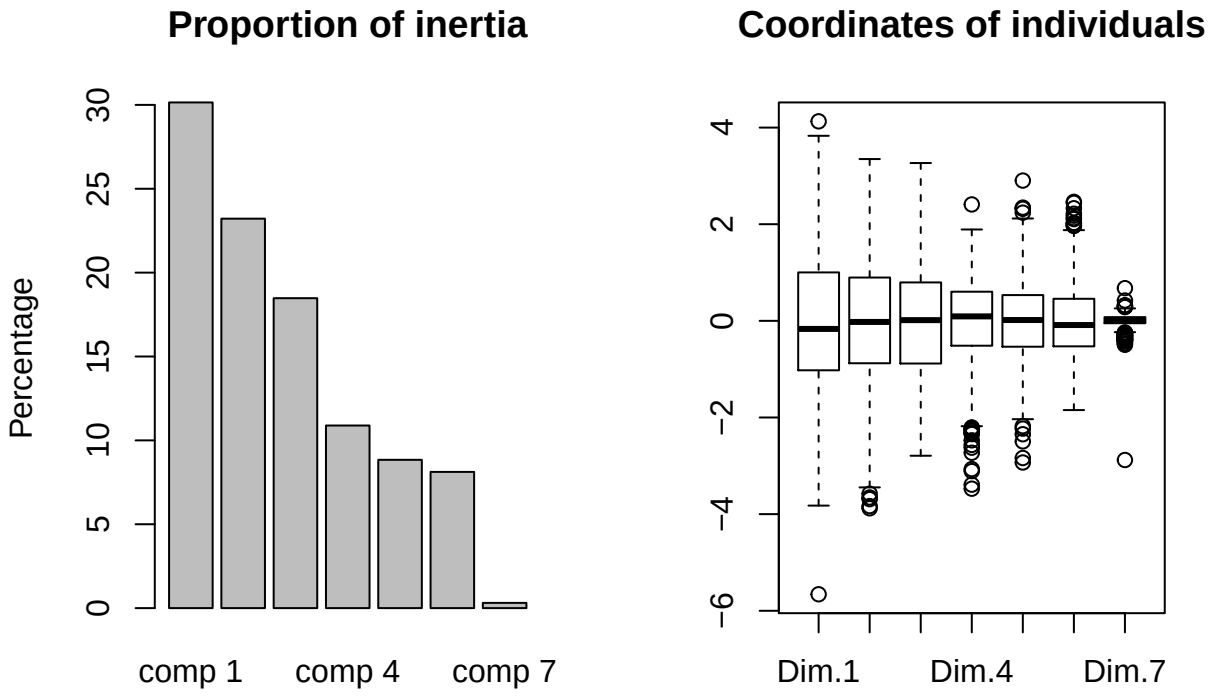
Analyse en composantes principales :

Permet d'analyser et de visualiser un jeu de données contenant des individus décrits par plusieurs variables quantitatives. cette méthode est utilisée pour extraire et visualiser les informations importantes contenues dans une table de données multivariées (données avec plusieurs variables).

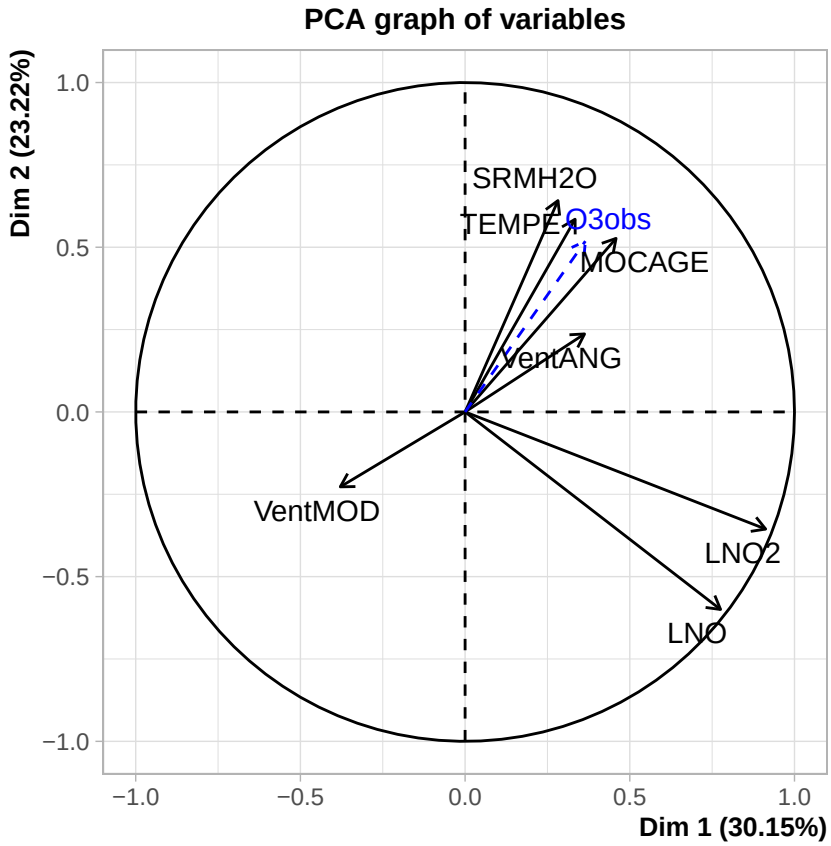
```
# ACP réduite
# Décroissance des valeurs propres
library(FactoMineR)
library(tidyr)
library(dplyr)
glimpse(ozone[, c(11,2:4, 6:10)])
```

```
## Rows: 1,041
## Columns: 9
## $ DepSeuil <fct> FALSE, FALSE, FALSE, FALSE, FALSE, FALSE, TRUE, FALSE, FALSE,~
## $ O3obs    <int> 91, 100, 82, 94, 107, 150, 164, 135, 121, 129, 118, 48, 97, 8~
## $ MOCAGE   <dbl> 93.2, 104.6, 103.6, 94.8, 99.0, 114.3, 127.7, 164.3, 144.1, 1~
## $ TEMPE    <dbl> 21.5, 20.2, 17.4, 18.8, 23.7, 23.6, 26.6, 23.5, 23.3, 23.7, 2~
## $ VentMOD  <dbl> 9.5000, 8.0100, 9.3771, 9.4578, 7.8791, 6.3127, 4.8042, 4.879~
## $ VentANG  <dbl> -0.64350, -0.04996, -0.12832, -0.34516, -0.41822, 0.06341, 0.~
## $ SRMH2O   <dbl> 0.09203260, 0.09386160, 0.09751923, 0.09246621, 0.08549854, 0~
## $ LNO2     <dbl> 0.4712528, 0.7518877, 0.5050087, 0.8544153, 0.5025918, 1.6707~
## $ LNO      <dbl> -0.858021824, -0.632993258, -0.761426021, -0.355247392, -0.79~
```

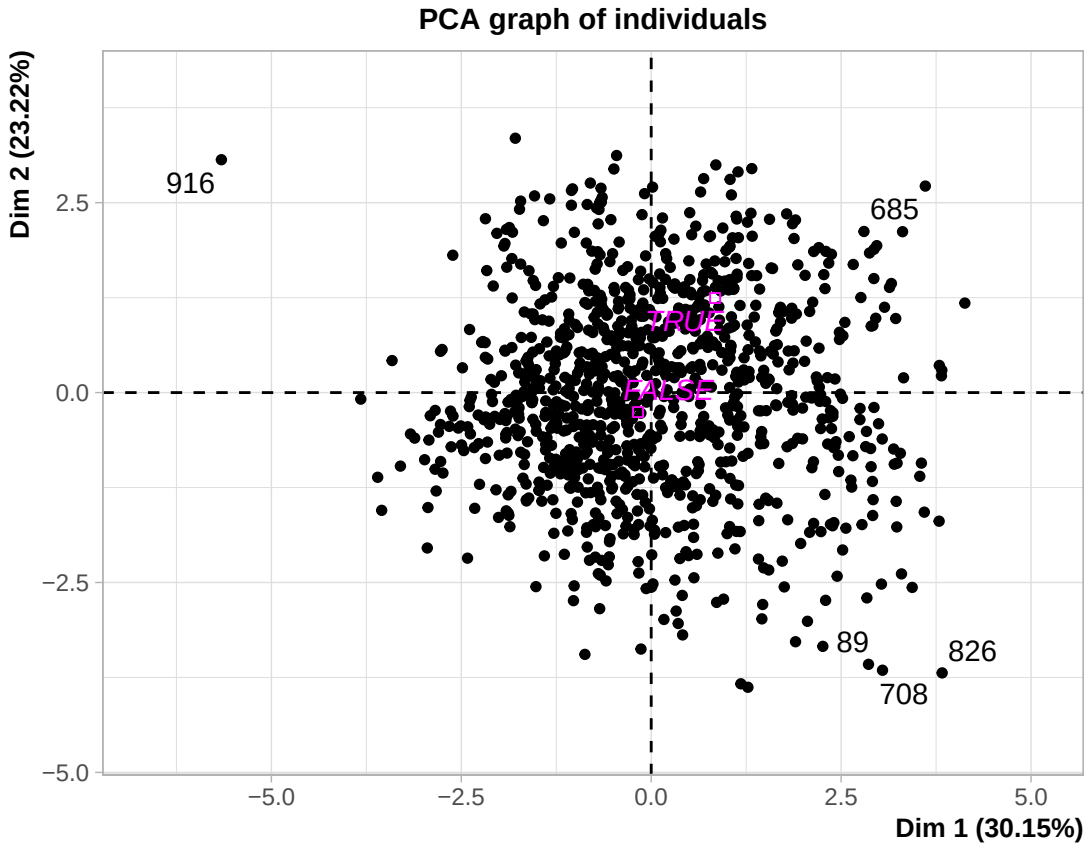
```
acp <- PCA(ozone[, c(11,2:4, 6:10)], scale.unit = TRUE,
           graph = FALSE, quali.sup = 1, quanti.sup = 2, ncp = 7)
options(repr.plot.width = 8, repr.plot.height = 4)
par(mfrow = c(1, 2))
barplot(acp$eig[, 2], ylab = "Percentage", main = "Proportion of inertia")
boxplot(acp$ind$coord, main = "Coordinates of individuals")
```




```
plot(acp, choix = "varcor")
```




```
plot(acp, choix = "ind", select = "contrib 5", unselect = 0)
```



Q-3 - Que sont ces graphiques?

-> Pour le premier graph c'est le cercle des correlation des sept variables sélectionnées. -> Pour le deuxième graph c'est le nuage de points des individus en deux dimensions.

Q- Que dire du choix de la dimension, des valeurs atypiques?

Le choix des dimensions est le facteur principale qui détermine la qualité d'une ACP.

```
library("factoextra")
```

```
## Welcome! Want to learn more? See two factoextra-related books at https://goo.gl/ve3WBa
```

```
eig.val <- get_eigenvalue(acp)
eig.val
```

```
##       eigenvalue variance.percent cumulative.variance.percent
## Dim.1 2.11028586       30.1469408                    30.14694
## Dim.2 1.62520441       23.2172058                    53.36415
## Dim.3 1.29335091       18.4764416                    71.84059
## Dim.4 0.76195442       10.8850632                    82.72565
## Dim.5 0.61891654        8.8416649                    91.56732
## Dim.6 0.56848881        8.1212687                    99.68859
## Dim.7 0.02179904        0.3114149                   100.00000
```

```
#acp$eig
```

Le choix n'est pas le meilleur dans ce cas car la somme des dimensions est loin de la valeur 100%, dans notre en deux dimensions on peut représenter 53% de nos données. Dans notre analyse, les trois premières composantes principales expliquent 75% de la variation. C'est un pourcentage acceptable. Une autre méthode pour déterminer le nombre de composantes principales est de regarder le graphique des valeurs propres

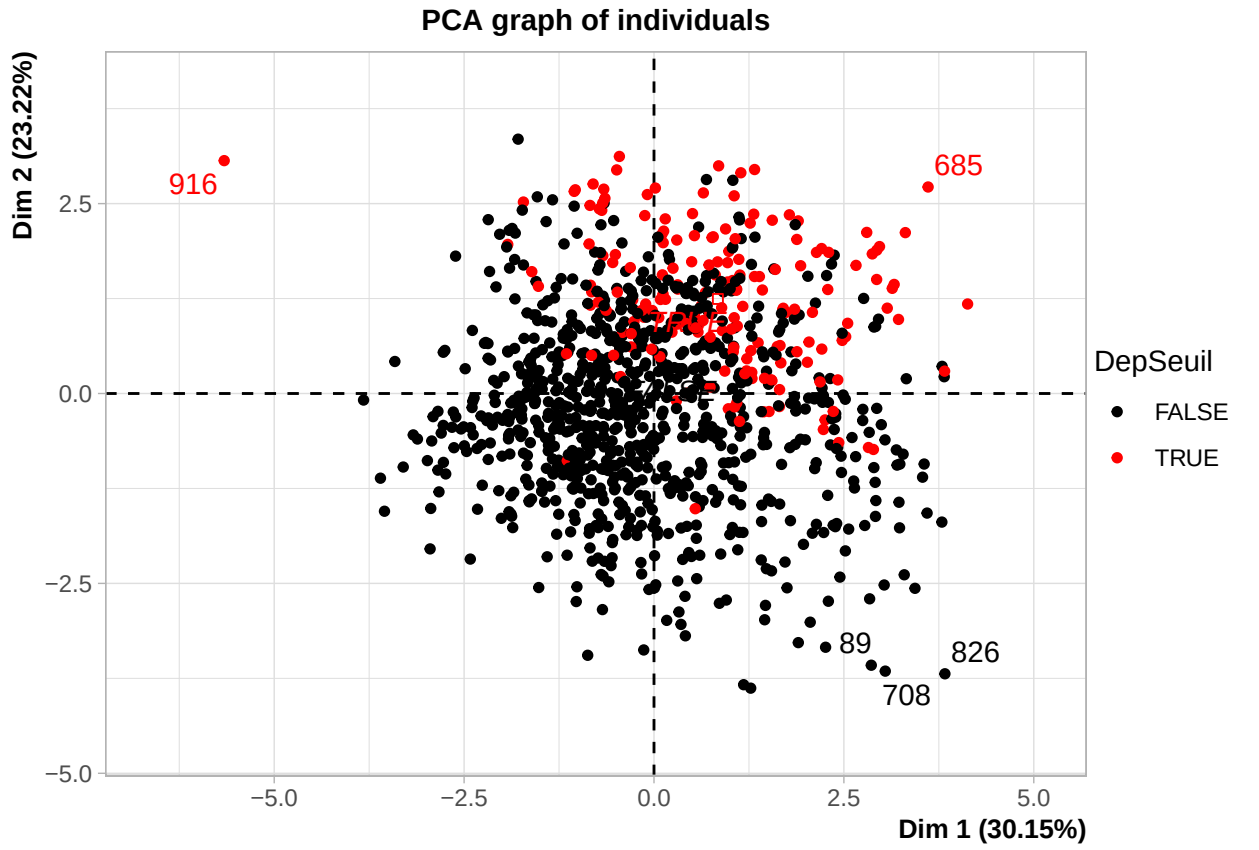
(appelé scree plot). Les points qui sont loin sont considéré comme des variable atypique contrairement aux valeurs qui sont proches l'une par rapport à l'autre

Q- Que dire de la structure de corrélation des variables ? Est-elle intuitive ?

Plus les deux variables sont proches, plus sont corrélées entre elles et plus elles sont loin de l'origine plus elles sont liées. La distance entre les variables et l'origine mesure la qualité de représentation des variables. Les variables qui sont loin de l'origine sont bien représentées par l'ACP (flèche plus grande) par exemple la flèche de LNO et LNO2 est la plus grande comme le montre dans le graphe de cercle de correlation - plus deux variables sont corrélées, plus leurs flèches pointent dans la même direction.

Même graphe en coloriant les dépassement de seuil la concentration d'ozone (150 μg).

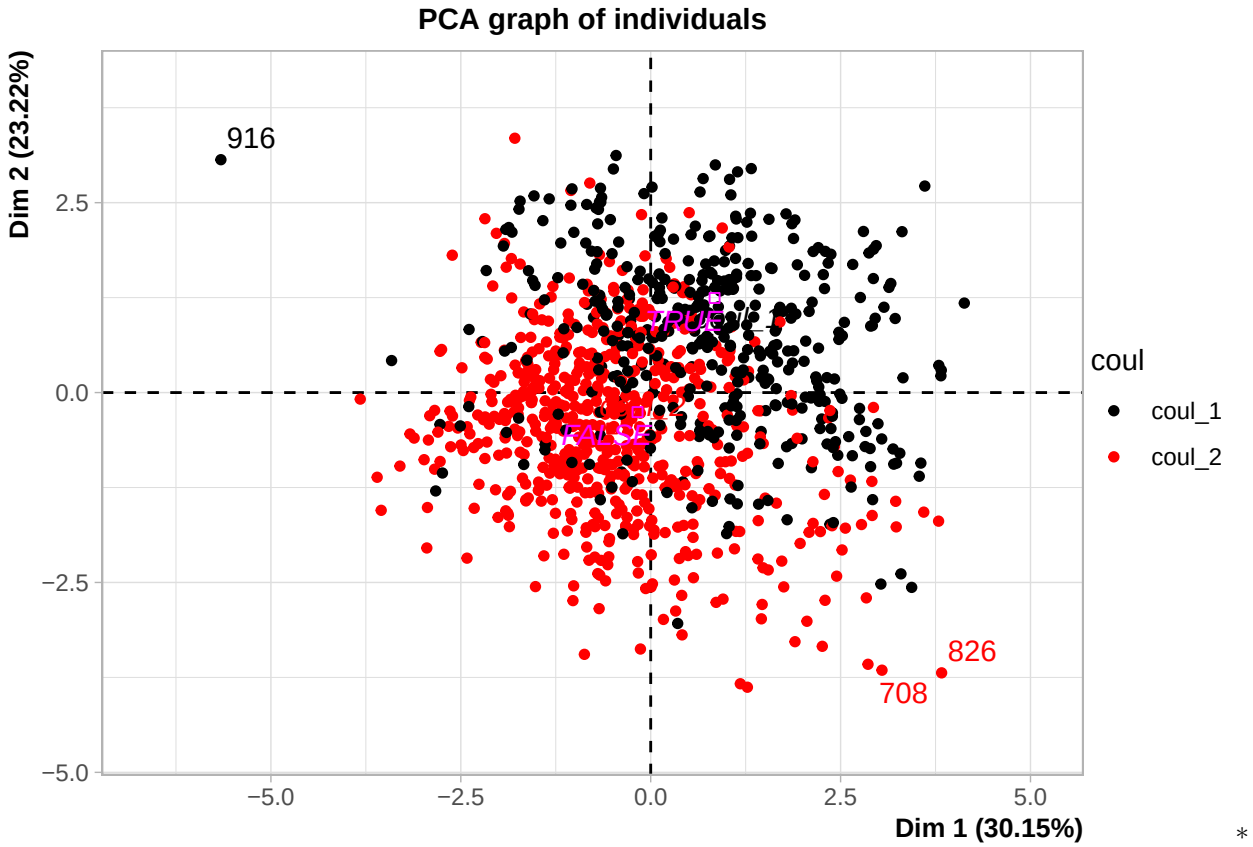
```
plot(acp, choix = "ind", habillage = 1,
     select = "contrib 5", unselect = 0)
```



Q- Une discrimination linéaire (hyperplan) semble-t-elle possible ?

Réponse : je penses qu'une discrimination linéaire semble possible à faire, en changeant de repére et les dimentions ,mais elle n'est pas très utile.

```
km.ozone <- kmeans(ozone[, c(3:4, 6:10)], centers = 2)
# Représentation dans les coordonnées de l'acp
acp2 <- PCA(cbind(coul = as.factor(km.ozone$cluster),
          ozone[, c(11, 3:4, 6:10)]), scale.unit = TRUE,
          graph = FALSE, quali.sup = 1:2, ncp = 7)
plot(acp2, choix = "ind", habillage = "coul",
     select = "contrib 3", unselect = 0)
```



Donne t-elle la même information ? L'algorithme k-means donne plus d'informations sur la classification des données (plus de précision).

Protocole de comparaison

Q- Commenta appelle-t-on cette procédure spécifique de validation croisée ?

Train Test Split c'est une approche de l'apprentissage supervisé.

Extraction des échantillons

Les commandes ci-dessous réalisent l'extraction du sous-ensemble des données d'apprentissage et de test.

```
set.seed(111) # initialisation du générateur
# Extraction des échantillons
test.ratio <- .2   # part de l'échantillon test
npop <- nrow(ozone) # nombre de lignes dans les données
nvar <- ncol(ozone) # nombre de colonnes
# taille de l'échantillon test
ntest <- ceiling(npop * test.ratio)
# indices de l'échantillon test
testi <- sample(1:npop, ntest)
# indices de l'échantillon d'apprentissage
appri <- setdiff(1:npop, testi)
```

Construction des échantillons pour la régression: prévision de la concentration en ozone.

```
# construction de l'échantillon d'apprentissage
datappr <- ozone[appri, -11]
# construction de l'échantillon test
```

```
datestr <- ozone[testi, -11]
# vérification
str(datappr)
```

```
## 'data.frame':    832 obs. of  10 variables:
##  $ JOUR   : Factor w/ 2 levels "0","1": 2 2 1 1 1 1 1 2 2 1 ...
##  $ O3obs  : int  91 100 82 94 107 150 164 135 121 129 ...
##  $ MOCAGE : num  93.2 104.6 103.6 94.8 99 ...
##  $ TEMPE  : num  21.5 20.2 17.4 18.8 23.7 23.6 26.6 23.5 23.3 23.7 ...
##  $ STATION: Factor w/ 5 levels "Aix","Als","Cad",..: 1 1 1 1 1 1 1 1 1 1 ...
##  $ VentMOD: num  9.5 8.01 9.38 9.46 7.88 ...
##  $ VentANG: num  -0.643 -0.05 -0.128 -0.345 -0.418 ...
##  $ SRMH2O : num  0.092 0.0939 0.0975 0.0925 0.0855 ...
##  $ LNO2   : num  0.471 0.752 0.505 0.854 0.503 ...
##  $ LNO    : num  -0.858 -0.633 -0.761 -0.355 -0.794 ...
```

```
str(datestr)
```

```
## 'data.frame':    209 obs. of  10 variables:
##  $ JOUR   : Factor w/ 2 levels "0","1": 1 1 1 2 1 1 1 2 2 2 ...
##  $ O3obs  : int  135 143 71 77 79 155 101 75 114 156 ...
##  $ MOCAGE : num  127.8 189.7 103.9 73 87.8 ...
##  $ TEMPE  : num  18.8 21 25.9 23.5 12.3 32.2 19.4 27.6 24.9 27 ...
##  $ STATION: Factor w/ 5 levels "Aix","Als","Cad",..: 3 4 1 5 5 1 2 3 4 2 ...
##  $ VentMOD: num  2.1 3.14 10.68 4.3 4.6 ...
##  $ VentANG: num  -0.0476 0.6499 -0.7523 0.0232 -0.77 ...
##  $ SRMH2O : num  0.0865 0.1155 0.068 0.0782 0.0906 ...
##  $ LNO2   : num  0.331 -0.456 1.043 0.178 1.028 ...
##  $ LNO    : num  -1.411 -2.551 -0.428 -1.238 -0.272 ...
```

```
#summary(datappr)
```

Construction des échantillons pour la discrimination: prévision de dépassement.

```
# construction de l'échantillon d'apprentissage
datappq <- ozone[appri,-2]
# construction de l'échantillon test
datestq <- ozone[testi,-2]
# vérification
str(datappq)
```

```
## 'data.frame':    832 obs. of  10 variables:
##  $ JOUR    : Factor w/ 2 levels "0","1": 2 2 1 1 1 1 1 2 2 1 ...
##  $ MOCAGE  : num  93.2 104.6 103.6 94.8 99 ...
##  $ TEMPE   : num  21.5 20.2 17.4 18.8 23.7 23.6 26.6 23.5 23.3 23.7 ...
##  $ STATION : Factor w/ 5 levels "Aix","Als","Cad",..: 1 1 1 1 1 1 1 1 1 1 ...
##  $ VentMOD : num  9.5 8.01 9.38 9.46 7.88 ...
##  $ VentANG : num  -0.643 -0.05 -0.128 -0.345 -0.418 ...
##  $ SRMH2O  : num  0.092 0.0939 0.0975 0.0925 0.0855 ...
##  $ LNO2    : num  0.471 0.752 0.505 0.854 0.503 ...
##  $ LNO     : num  -0.858 -0.633 -0.761 -0.355 -0.794 ...
##  $ DepSeuil: Factor w/ 2 levels "FALSE","TRUE": 1 1 1 1 1 1 2 1 1 1 ...
```

```
str(datestq)
```

```
## 'data.frame':    209 obs. of  10 variables:
##  $ JOUR    : Factor w/ 2 levels "0","1": 1 1 1 2 1 1 1 2 2 2 ...
```

```
##  $ MOCAGE  : num  127.8 189.7 103.9 73 87.8 ...
##  $ TEMPE   : num  18.8 21 25.9 23.5 12.3 32.2 19.4 27.6 24.9 27 ...
##  $ STATION : Factor w/ 5 levels "Aix","Als","Cad",..: 3 4 1 5 5 1 2 3 4 2 ...
##  $ VentMOD : num  2.1 3.14 10.68 4.3 4.6 ...
##  $ VentANG : num  -0.0476 0.6499 -0.7523 0.0232 -0.77 ...
##  $ SRMH2O  : num  0.0865 0.1155 0.068 0.0782 0.0906 ...
##  $ LNO2    : num  0.331 -0.456 1.043 0.178 1.028 ...
##  $ LNO     : num  -1.411 -2.551 -0.428 -1.238 -0.272 ...
##  $ DepSeuil: Factor w/ 2 levels "FALSE","TRUE": 1 1 1 1 1 2 1 1 1 2 ...
```

```
#summary(datappq)
```

Enfin, avant de passer aux différents algorithmes, définissons une fonction traçant le graphe des résidus avec des couleurs et des échelles fixes sur les axes (à utiliser pour tracer l'erreur).

```
options(repr.plot.width = 8, repr.plot.height = 4)
# Définition d'une fonction pour un graphe coloré et des échelles fixes sur les
# axes
plot.res <- function(x, y, titre = "titre") {
    plot(x, y, col = "blue", xlim = c(0, 250), ylim = c(-100, 100), ylab = "Résidus",
        xlab = "Valeurs prédites", main = titre, pch = 20)
    # points(x2, y, col='red')
    abline(h = 0, col = "green")
}
```

832 : individus pour l'apprentissage. 209 : individus pour le test.

Prévision par modèle gaussien

Modèle linéaire

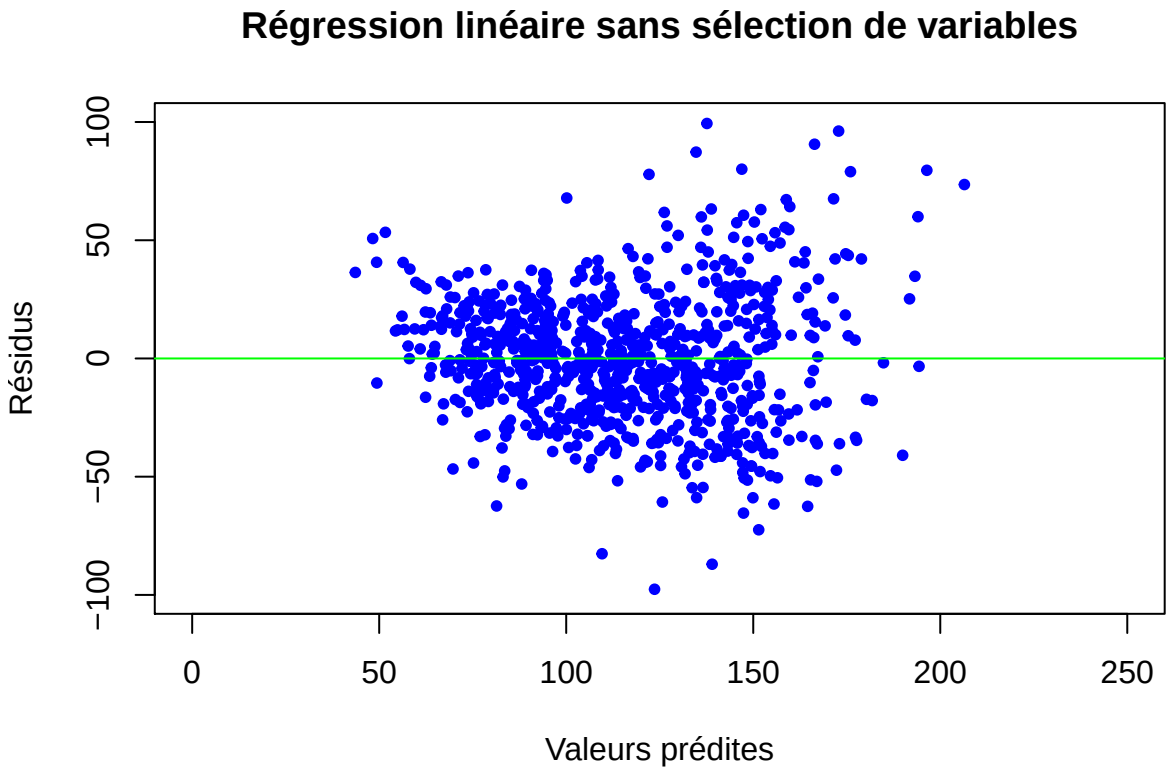
-> Sans sélection de variables

Le modèle de régression linéaire simple intégre des variables qualitatives; c'est dans ce cas une analyse de covariance estimée par la fonction aov mieux adaptée à ce modèle.

```
# estimation du modèle sans interaction
reg.lm <- aov(O3obs ~ . , data = datappr)

# Extraction des résidus et des valeurs ajustées de ce modèle
res.lm <- reg.lm$residuals
fit.lm <- reg.lm$fitted.values

# Graphe des résidus.
plot.res(fit.lm,res.lm,"Régression linéaire sans sélection de variables")
```



Q - Que dire de la distribution de ces résidus?

Réponse Pas de linéarité

Q - La forme du nuage renseigne sur les hypothèses de linéarité du modèle et d'homoscédasticité. Que dire de la validité de ce modèle ?

RéponseLa figure montre que le résidu n'apporte pas de changement avec X , par contre on remarque que la propagation n'est pas stable .

Le modèle est invalide par ce que le graphe des résidus versus les valeurs prédites ne présente pas de structure (indépendance, homoscédasticité, normalité).

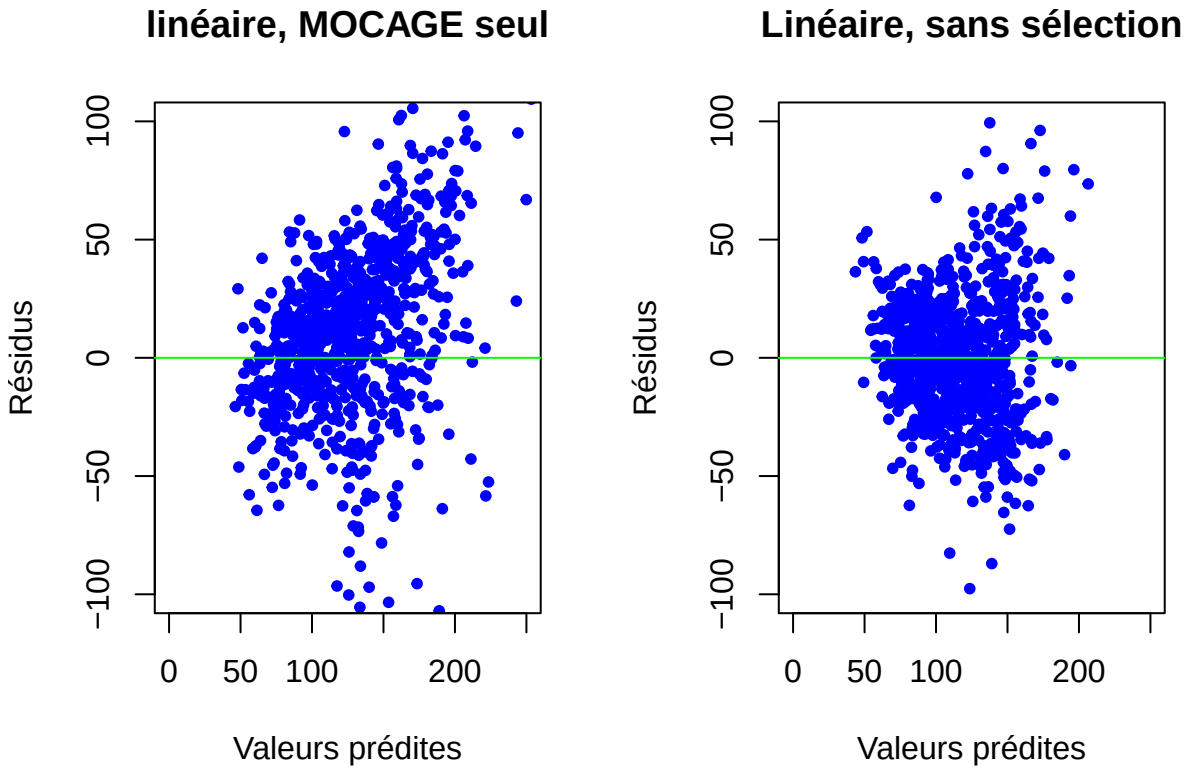
Apprécier néanmoins sa significativité par la commande suivante.

```
summary(reg.lm)
```

```
##              Df Sum Sq Mean Sq F value   Pr(>F)
## JOUR          1    106     106   0.134 0.714791
## MOCAGE        1 470173  470173 590.680  < 2e-16 ***
## TEMPE         1 225427  225427 283.204  < 2e-16 ***
## STATION       4  10163    2541   3.192 0.012926 *
## VentMOD       1  13846   13846  17.395 3.36e-05 ***
## VentANG       1  10088   10088  12.673 0.000392 ***
## SRMH2O        1    273     273   0.343 0.558101
## LNO2          1   3337    3337   4.193 0.040918 *
## LNO           1   9006    9006  11.314 0.000805 ***
## Residuals   819 651913     796
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Q - Ce premier modèle est comparé avec celui de la seule prévision déterministe MOCAGE. Qu'en conclure ?

```r
# Graphe des résidus du modèle déterministe MOCAGE
par(mfrow = c(1, 2))
plot.res(datappr[, "MOCAGE"],
         datappr[, "MOCAGE"] - datappr[, "O3obs"], "linéaire, MOCAGE seul")
plot.res(fit.lm, res.lm, "Linéaire, sans sélection")
```




```r
par(mfrow = c(1, 1))
```

Remarque : dans le modèle déterministe de la variable MOCAGE l'erreur est plus grande. d'où la variable MOCAGE influence sur le taux d'erreur. -> Sélection de variable par régularisation L1 (LASSO) [pour Minimiser la complexité du modèle]

```r
library(glmnet)
```

```
## Loading required package: Matrix
```

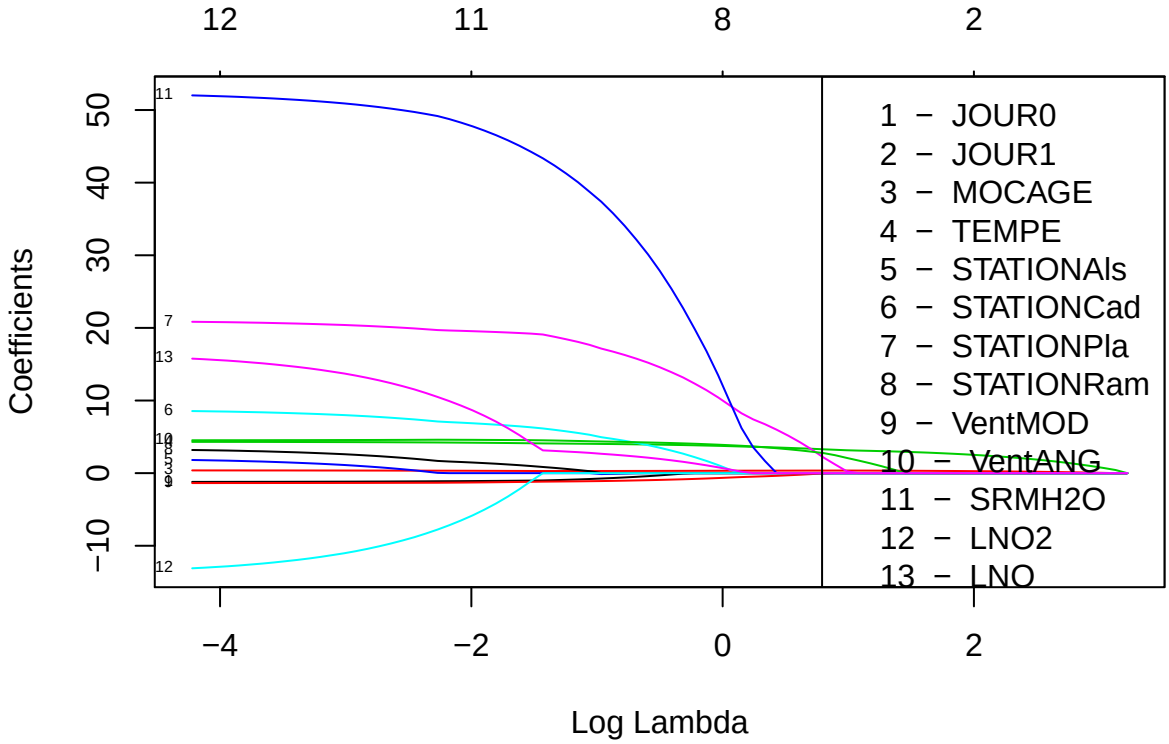
```
##
## Attaching package: 'Matrix'
```

```
## The following objects are masked from 'package:tidyr':
##
##     expand, pack, unpack
```

```
## Loaded glmnet 4.1-6
```

```r
library(Matrix)
# avec des variables quantitatives seulement
reg.lasso.quanti <- glmnet(y = datappr[, 2],
                           x = as.matrix(datappr[, -c(1, 2, 5)]))
# avec toutes les variables, créer d'abord la matrice d'expériences
# avec 'model.matrix' (penser à retirer l'intercept du modèle)
x.mat <- model.matrix(O3obs ~ . - 1, data = datappr)
```

```
reg.lasso <- glmnet(y = datappr$O3obs, x = x.mat)
options(repr.plot.width = 12, repr.plot.height = 10)
plot(reg.lasso, xvar = "lambda", label = TRUE)
legend("topright",
       legend = paste(1:ncol(x.mat), " - ", colnames(x.mat)))
```



Q - Que fait la commande model.matrix ? Comment sont gérées les variables catégorielles ?

Model.matrix permet de visualiser le modèle numerique crée par une formule et peut etre utile pour verifier un modèle. La commande model.matrix permet aussi de creer une matrice de modèle qui contient uniquement les variables quantitatives, et de modifier les variable categorielles en factor. Les variables catégorielles sont des objets de type factor, Si on souhaite intégrer une variable catégorielle à un modèle de régression linéaire, il y a deux méthodes. La première, est de définir le type de la variable dans le tableau qui contient les données (tibble, data.frame, ...). La seconde est d'utiliser la variable factor() dans la formule, lors de l'appel de la régression. La première méthode possède l'avantage de la lisibilité, surtout lorsque l'on souhaite définir la valeur de référence.

Q - Que représentent les courbes ci-dessus, appelées "chemins de régularisation"?

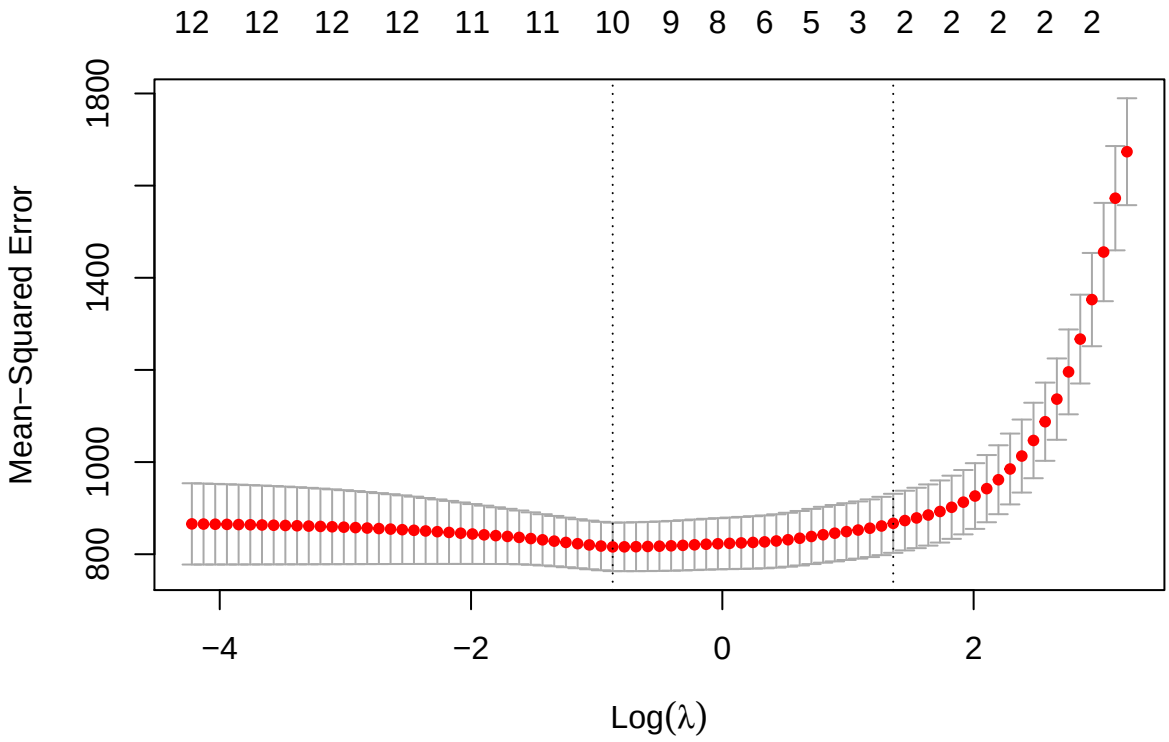
Les courbes ci-dessus representent : l'optimisations des residus pour chaque variabale dans le but d'avoir le moins de residus.

```
#help(model.matrix)
head(x.mat)
```

```
##   JOUR0 JOUR1 MOCAGE TEMPE STATIONAls STATIONCad STATIONPla STATIONRam VentMOD
## 1     0     1   93.2  21.5          0          0          0          0  9.5000
## 2     0     1  104.6  20.2          0          0          0          0  8.0100
## 3     1     0  103.6  17.4          0          0          0          0  9.3771
## 4     1     0   94.8  18.8          0          0          0          0  9.4578
## 5     1     0   99.0  23.7          0          0          0          0  7.8791
## 6     1     0  114.3  23.6          0          0          0          0  6.3127
```

```
##    VentANG     SRMH2O      LNO2        LNO
## 1 -0.64350 0.09203260 0.4712528 -0.8580218
## 2 -0.04996 0.09386160 0.7518877 -0.6329933
## 3 -0.12832 0.09751923 0.5050087 -0.7614260
## 4 -0.34516 0.09246621 0.8544153 -0.3552474
## 5 -0.41822 0.08549854 0.5025918 -0.7940731
## 6  0.06341 0.10871982 1.6707211  0.2949059
```

```
# choix du paramètre de régularisation par validation croisée
reg.lasso.cv <- cv.glmnet(y = datappr[, 2], x = x.mat)
plot(reg.lasso.cv)
```




```
library(glmnet)
help(cv.glmnet)
```

Q - Que représente la courbe rouge ? Et la bande qui est autour ?

La courbe rouge représente la minimisation de l'erreur quadratique moyenne des valeurs de coefficient de régularisation (Lamda), les valeurs autour représentant l'écart-type. La valeur optimale du paramètre de régularisation est celle qui correspond au minimum globale de l'erreur quadratique moyenne (EQM).

Q - Comment sont obtenues les valeurs de log(lambda) correspondant aux lignes verticales en pointillé ?

On applique la fonction cv.glmnet du package glmnet qui nous permet de lancer des validations croiser sur un set de modèles LASSO pour une range de lambda. On se retrouve donc avec plusieurs modèles LASSO associé chacun à une valeur de lambda différente. En utilisant la fonction plot on obtient directement le graphique représentant les MSE des modèles, aprés on peut extraire facilement le modèle associé au plus petit lambda.

```
# valeur estimée
paste("CV estimate of lambda :", round(reg.lasso.cv$lambda.1se, 3))
```

```
## [1] "CV estimate of lambda : 3.896"
```

```r
# modèle correspondant
coef(reg.lasso.cv, s = "lambda.1se")
```

```
## 14 x 1 sparse Matrix of class "dgCMatrix"
##                     s1
## (Intercept) 1.1658431
## JOUR0       .
## JOUR1       .
## MOCAGE      0.3370194
## TEMPE       2.9855716
## STATIONAls  .
## STATIONCad  .
## STATIONPla  .
## STATIONRam  .
## VentMOD     .
## VentANG     0.4939697
## SRMH2O      .
## LNO2        .
## LNO         .
```

Q Même question en choisissant l'autre valeur de lambda retenue par glmnet, i.e. "reg.lasso.cv$lambda.min"

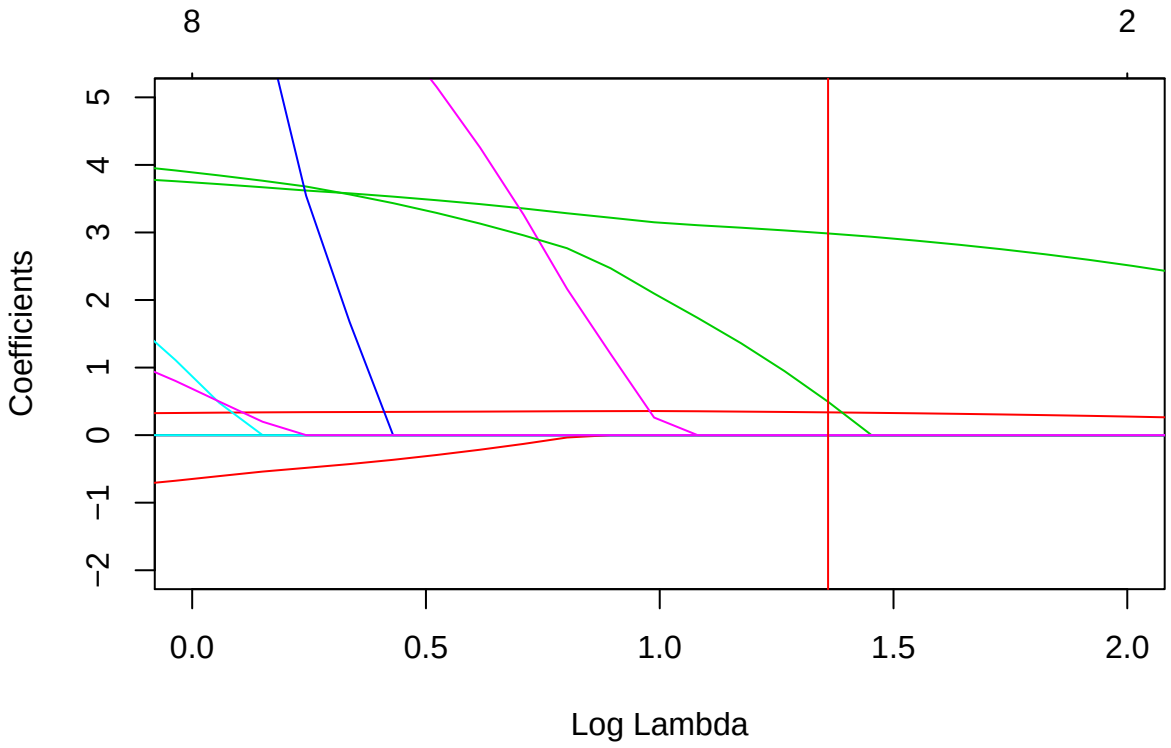
```r
# valeur estimée
paste("CV estimate of lambda :", round(reg.lasso.cv$lambda.min, 3))
```

```
## [1] "CV estimate of lambda : 0.418"
```

```r
# modèle correspondant
coef(reg.lasso.cv, s = "lambda.1se")
```

```
## 14 x 1 sparse Matrix of class "dgCMatrix"
##                     s1
## (Intercept) 1.1658431
## JOUR0       .
## JOUR1       .
## MOCAGE      0.3370194
## TEMPE       2.9855716
## STATIONAls  .
## STATIONCad  .
## STATIONPla  .
## STATIONRam  .
## VentMOD     .
## VentANG     0.4939697
## SRMH2O      .
## LNO2        .
## LNO         .
```

```r
# NEW :
plot(reg.lasso, xvar = "lambda", label = TRUE,xlim=c(0,2),ylim=c(-2,5))
abline(v=log(reg.lasso.cv$lambda.1se),col="red")
```



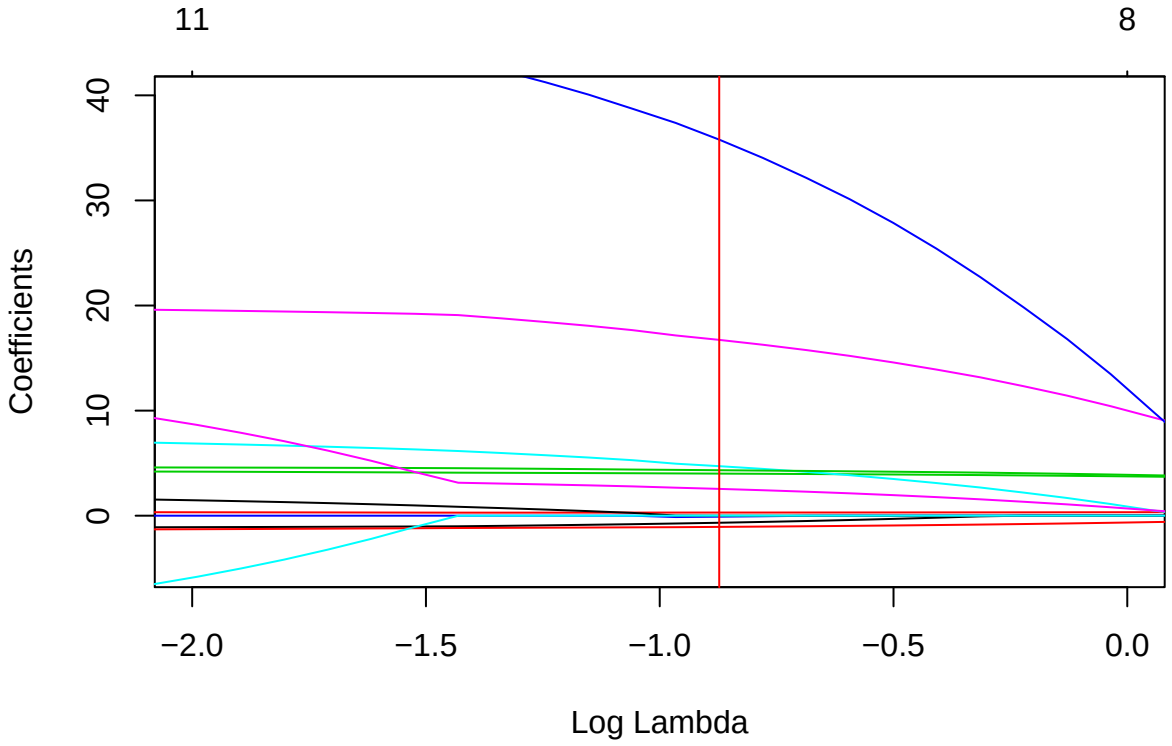

```
# NEW :
# valeur estimée
paste("CV estimate of lambda :", round(reg.lasso.cv$lambda.min, 3))
```

```
## [1] "CV estimate of lambda : 0.418"
```

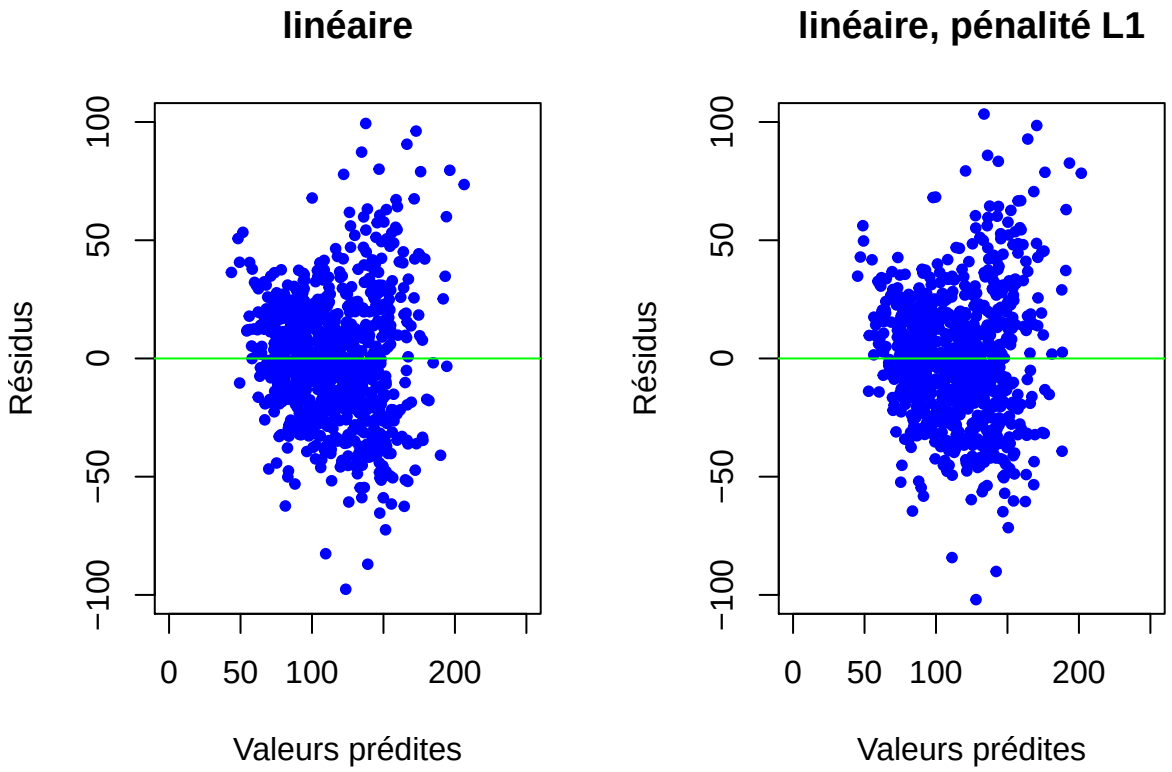
```
# modèle correspondant
coef(reg.lasso.cv, s = "lambda.min")
```

```
## 14 x 1 sparse Matrix of class "dgCMatrix"
##                         s1
## (Intercept) -18.02986736
## JOUR0        -0.67101204
## JOUR1         .
## MOCAGE        0.29912279
## TEMPE         4.00531665
## STATIONAls   -0.09333231
## STATIONCad    4.71348395
## STATIONPla   16.73098026
## STATIONRam    .
## VentMOD      -1.06568750
## VentANG       4.32796699
## SRMH2O       35.78513984
## LNO2          .
## LNO           2.55034443
```

```
plot(reg.lasso, xvar = "lambda", label = TRUE,xlim=c(-2,0),ylim=c(-5,40))
abline(v=log(reg.lasso.cv$lambda.min),col="red")
```




```
# Extraction des valeurs ajustées et des résidus
fit.lasso <- predict(reg.lasso.cv, s = "lambda.min", newx = x.mat)
res.lasso <- datappr$O3obs - fit.lasso
# Graphe des résidus
options(repr.plot.width = 8, repr.plot.height = 4)
par(mfrow = c(1, 2))
plot.res(fit.lm, res.lm, "linéaire")
plot.res(fit.lasso, res.lasso, "linéaire, pénalité L1")
```

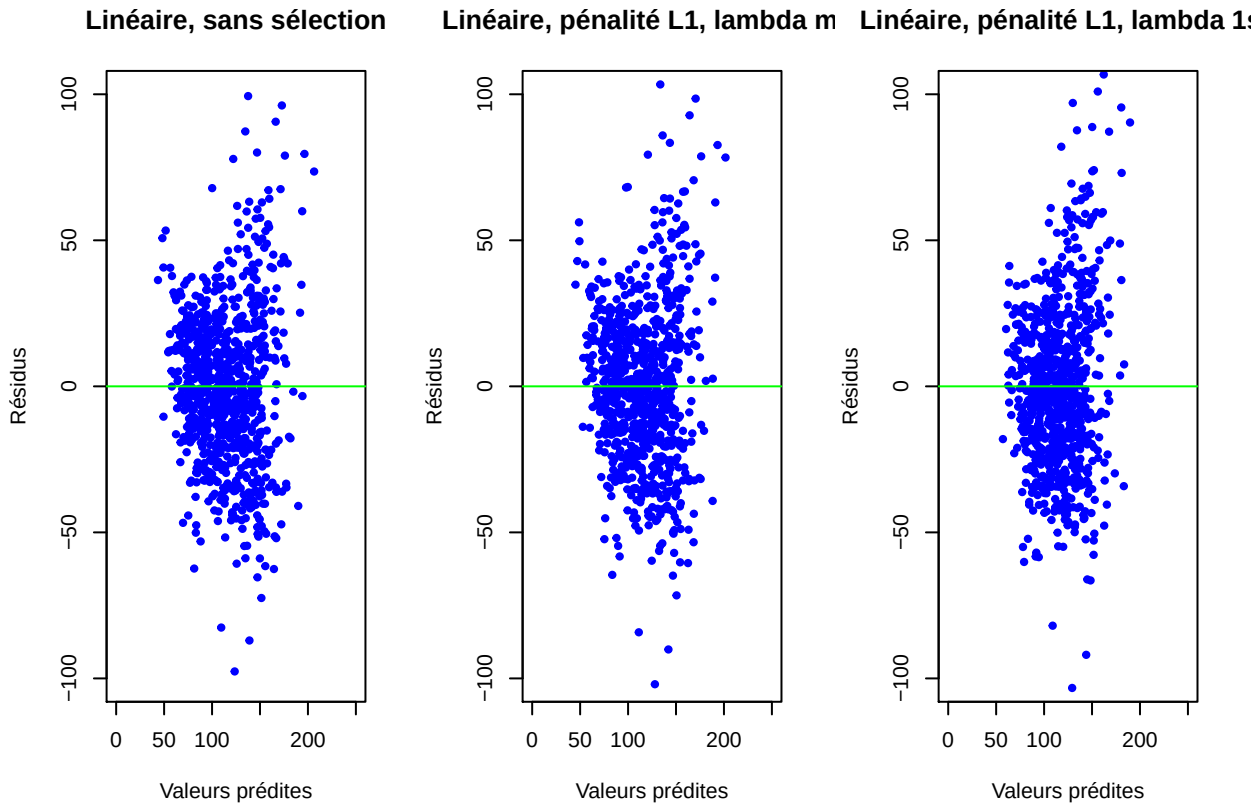



```
# Extraction des valeurs ajustées et des résidus

fit.lasso <- predict(reg.lasso.cv, s = "lambda.min", newx = x.mat)
res.lasso <- datappr$O3obs - fit.lasso

fit.lasso.1se <- predict(reg.lasso.cv, s = "lambda.1se", newx = x.mat) # NEW
res.lasso.1se <- datappr$O3obs - fit.lasso.1se # NEW

# Graphe des résidus
options(repr.plot.width = 12, repr.plot.height = 4)
par(mfrow = c(1, 3))
plot.res(fit.lm, res.lm, "Linéaire, sans sélection")
plot.res(fit.lasso, res.lasso, "Linéaire, pénalité L1, lambda min")
plot.res(fit.lasso.1se, res.lasso.1se, "Linéaire, pénalité L1, lambda 1se") # NEW
```



Q - Calculer le critère MSE (moyenne des carrés des résidus) pour les deux modèles. Pourquoi celui obtenu par LASSO est-il moins bon ? Quel critère LASSO minimise t-il ?

Il y'a pas une grande différence, le critère qui minimise lasso est la valeur de lambda

Q - Estimer l'erreur de généralisation du modèle de régression linéaire simple sans sélection de variables par validation croisée. Comparer avec celle du LASSO. Qu'observez-vous?

```
# NEW :
paste("Modèle linéaire sans séletion:",mean(res.lm^2))
```

```
## [1] "Modèle linéaire sans séletion: 783.549239590938"
```

```
paste("LASSO avec lambda.min:",mean(res.lasso^2))
```

```
## [1] "LASSO avec lambda.min: 793.58476401389"
```

```
paste("LASSO avec lambda.1se:",mean(res.lasso.1se^2))
```

```
## [1] "LASSO avec lambda.1se: 859.648320971249"
```

```
# NEW
V=10 ; nV=floor(nrow(datappr)/V)
S=sample(1:nrow(datappr),replace=FALSE)
error.CV = c()
for(v in 1:V)
{ # Rq : les deux dernières obs sont tjs dans l'échantillon d'apprentissage...
    datappr.learn=datappr[-c(S[(nV*(v-1)):(nV*v)]),]
    datappr.valid=datappr[c(S[(nV*(v-1)):(nV*v)]),]
    error.CV=c(error.CV,mean((datappr.valid$O3obs-predict(aov(O3obs ~ ., data=datappr.learn),newdata=da
}
mean(error.CV)
```

```
## [1] 865.6682
```

```
print(reg.lasso.cv)
```

```
##
## Call:  cv.glmnet(x = x.mat, y = datappr[, 2])
##
## Measure: Mean-Squared Error
##
##     Lambda Index Measure    SE Nonzero
## min  0.418    45   815.9 52.58      10
## 1se  3.896    21   867.0 64.04       3
```

Modèle quadratique

Sélection de variables par critère AIC Q - Quel autre critère, équivalent à AIC dans le cas gaussien et de variance résiduelle connue, est utilisée en régression linéaire ?

```
Le critère d'information bayésien (en anglais bayesian information criterion ; en abrégé BIC) est une d
  {\mathit  {BIC}}=-2\ln(L)+\ln(n)k
```

```
# Estimation du modèle de toute interaction d'ordre 2
reg.glm <- glm(O3obs ~ .^2, data = datappr)
# Recherche du meilleur modèle au sens
# du critère d'Akaïke par méthode descendante
reg.glm.step <- step(reg.glm, direction = "backward")
```

```
## Start:  AIC=7783.44
## O3obs ~ (JOUR + MOCAGE + TEMPE + STATION + VentMOD + VentANG +
##     SRMH2O + LNO2 + LNO)^2
##
##                   Df Deviance    AIC
## - JOUR:STATION     4   471877 7776.5
## - STATION:VentANG  4   471970 7776.7
## - JOUR:TEMPE       1   471262 7781.4
## - JOUR:LNO2        1   471262 7781.4
## - LNO2:LNO         1   471263 7781.4
## - JOUR:SRMH2O      1   471265 7781.4
## - MOCAGE:TEMPE     1   471270 7781.5
## - JOUR:LNO         1   471321 7781.5
## - JOUR:MOCAGE      1   471324 7781.6
## - VentMOD:VentANG  1   471374 7781.6
## - JOUR:VentANG     1   471464 7781.8
## - MOCAGE:VentANG   1   471510 7781.9
## - MOCAGE:STATION   4   475115 7782.2
## - JOUR:VentMOD     1   471774 7782.3
## - VentANG:SRMH2O   1   471804 7782.4
## - MOCAGE:SRMH2O    1   471846 7782.5
## - VentMOD:LNO2     1   472012 7782.8
## - TEMPE:VentMOD    1   472318 7783.3
## <none>                 471261 7783.4
## - VentMOD:LNO      1   472416 7783.5
## - MOCAGE:VentMOD   1   472452 7783.5
## - STATION:LNO      4   476488 7784.6
## - VentANG:LNO2     1   473094 7784.7
```

```
## - VentMOD:SRMH2O   1   473263 7785.0
## - TEMPE:VentANG    1   473577 7785.5
## - SRMH2O:LNO2      1   473719 7785.8
## - SRMH2O:LNO       1   473881 7786.1
## - MOCAGE:LNO       1   474066 7786.4
## - VentANG:LNO      1   474390 7786.9
## - STATION:VentMOD  4   477962 7787.2
## - STATION:LNO2     4   478328 7787.8
## - MOCAGE:LNO2      1   475109 7788.2
## - TEMPE:LNO        1   475504 7788.9
## - TEMPE:LNO2       1   477011 7791.5
## - TEMPE:STATION    4   484266 7798.1
## - STATION:SRMH2O   4   486603 7802.1
## - TEMPE:SRMH2O     1   488461 7811.3
##
## Step:  AIC=7776.53
## O3obs ~ JOUR + MOCAGE + TEMPE + STATION + VentMOD + VentANG +
##     SRMH2O + LNO2 + LNO + JOUR:MOCAGE + JOUR:TEMPE + JOUR:VentMOD +
##     JOUR:VentANG + JOUR:SRMH2O + JOUR:LNO2 + JOUR:LNO + MOCAGE:TEMPE +
##     MOCAGE:STATION + MOCAGE:VentMOD + MOCAGE:VentANG + MOCAGE:SRMH2O +
##     MOCAGE:LNO2 + MOCAGE:LNO + TEMPE:STATION + TEMPE:VentMOD +
##     TEMPE:VentANG + TEMPE:SRMH2O + TEMPE:LNO2 + TEMPE:LNO + STATION:VentMOD +
##     STATION:VentANG + STATION:SRMH2O + STATION:LNO2 + STATION:LNO +
##     VentMOD:VentANG + VentMOD:SRMH2O + VentMOD:LNO2 + VentMOD:LNO +
##     VentANG:SRMH2O + VentANG:LNO2 + VentANG:LNO + SRMH2O:LNO2 +
##     SRMH2O:LNO + LNO2:LNO
##
##                    Df Deviance    AIC
## - STATION:VentANG  4   472669 7769.9
## - LNO2:LNO         1   471881 7774.5
## - JOUR:LNO2        1   471882 7774.5
## - JOUR:SRMH2O      1   471883 7774.5
## - MOCAGE:TEMPE     1   471891 7774.6
## - JOUR:LNO         1   471894 7774.6
## - JOUR:TEMPE       1   471952 7774.7
## - JOUR:VentANG     1   471976 7774.7
## - VentMOD:VentANG  1   471995 7774.7
## - JOUR:MOCAGE      1   472022 7774.8
## - MOCAGE:VentANG   1   472086 7774.9
## - MOCAGE:STATION   4   475743 7775.3
## - JOUR:VentMOD     1   472347 7775.4
## - MOCAGE:SRMH2O    1   472458 7775.6
## - VentANG:SRMH2O   1   472460 7775.6
## - VentMOD:LNO2     1   472527 7775.7
## - VentMOD:LNO      1   472923 7776.4
## - TEMPE:VentMOD    1   472927 7776.4
## - MOCAGE:VentMOD   1   472946 7776.4
## <none>                 471877 7776.5
## - STATION:LNO      4   476969 7777.5
## - VentANG:LNO2     1   473613 7777.6
## - VentMOD:SRMH2O   1   473915 7778.1
## - TEMPE:VentANG    1   474270 7778.7
## - SRMH2O:LNO2      1   474347 7778.9
## - SRMH2O:LNO       1   474491 7779.1
```

```
## - MOCAGE:LNO       1   474610 7779.3
## - VentANG:LNO      1   474946 7779.9
## - STATION:VentMOD  4   478645 7780.4
## - STATION:LNO2     4   478765 7780.6
## - MOCAGE:LNO2      1   475749 7781.3
## - TEMPE:LNO        1   476105 7781.9
## - TEMPE:LNO2       1   477639 7784.6
## - TEMPE:STATION    4   485159 7791.6
## - STATION:SRMH2O   4   487251 7795.2
## - TEMPE:SRMH2O     1   489231 7804.6
##
## Step:  AIC=7769.92
## O3obs ~ JOUR + MOCAGE + TEMPE + STATION + VentMOD + VentANG +
##     SRMH2O + LNO2 + LNO + JOUR:MOCAGE + JOUR:TEMPE + JOUR:VentMOD +
##     JOUR:VentANG + JOUR:SRMH2O + JOUR:LNO2 + JOUR:LNO + MOCAGE:TEMPE +
##     MOCAGE:STATION + MOCAGE:VentMOD + MOCAGE:VentANG + MOCAGE:SRMH2O +
##     MOCAGE:LNO2 + MOCAGE:LNO + TEMPE:STATION + TEMPE:VentMOD +
##     TEMPE:VentANG + TEMPE:SRMH2O + TEMPE:LNO2 + TEMPE:LNO + STATION:VentMOD +
##     STATION:SRMH2O + STATION:LNO2 + STATION:LNO + VentMOD:VentANG +
##     VentMOD:SRMH2O + VentMOD:LNO2 + VentMOD:LNO + VentANG:SRMH2O +
##     VentANG:LNO2 + VentANG:LNO + SRMH2O:LNO2 + SRMH2O:LNO + LNO2:LNO
##
##                   Df Deviance    AIC
## - JOUR:SRMH2O      1   472669 7767.9
## - JOUR:LNO2        1   472669 7767.9
## - LNO2:LNO         1   472669 7767.9
## - MOCAGE:TEMPE     1   472690 7768.0
## - VentMOD:VentANG  1   472694 7768.0
## - JOUR:LNO         1   472702 7768.0
## - JOUR:TEMPE       1   472732 7768.0
## - JOUR:MOCAGE      1   472761 7768.1
## - JOUR:VentANG     1   472817 7768.2
## - JOUR:VentMOD     1   473064 7768.6
## - MOCAGE:STATION   4   476643 7768.9
## - MOCAGE:SRMH2O    1   473246 7768.9
## - VentANG:SRMH2O   1   473278 7769.0
## - VentMOD:LNO2     1   473315 7769.1
## - TEMPE:VentMOD    1   473577 7769.5
## - MOCAGE:VentANG   1   473648 7769.6
## - VentMOD:LNO      1   473648 7769.6
## - MOCAGE:VentMOD   1   473723 7769.8
## <none>                 472669 7769.9
## - STATION:LNO      4   477888 7771.1
## - VentMOD:SRMH2O   1   474864 7771.8
## - TEMPE:VentANG    1   474994 7772.0
## - VentANG:LNO2     1   475028 7772.1
## - SRMH2O:LNO2      1   475160 7772.3
## - SRMH2O:LNO       1   475309 7772.6
## - MOCAGE:LNO       1   475398 7772.7
## - STATION:VentMOD  4   478962 7772.9
## - VentANG:LNO      1   475949 7773.7
## - STATION:LNO2     4   479570 7774.0
## - MOCAGE:LNO2      1   476732 7775.0
## - TEMPE:LNO        1   476882 7775.3
```

```
## - TEMPE:LNO2       1   478472 7778.1
## - TEMPE:STATION    4   486006 7785.1
## - STATION:SRMH2O   4   488545 7789.4
## - TEMPE:SRMH2O     1   490597 7798.9
##
## Step:  AIC=7767.92
## O3obs ~ JOUR + MOCAGE + TEMPE + STATION + VentMOD + VentANG +
##     SRMH2O + LNO2 + LNO + JOUR:MOCAGE + JOUR:TEMPE + JOUR:VentMOD +
##     JOUR:VentANG + JOUR:LNO2 + JOUR:LNO + MOCAGE:TEMPE + MOCAGE:STATION +
##     MOCAGE:VentMOD + MOCAGE:VentANG + MOCAGE:SRMH2O + MOCAGE:LNO2 +
##     MOCAGE:LNO + TEMPE:STATION + TEMPE:VentMOD + TEMPE:VentANG +
##     TEMPE:SRMH2O + TEMPE:LNO2 + TEMPE:LNO + STATION:VentMOD +
##     STATION:SRMH2O + STATION:LNO2 + STATION:LNO + VentMOD:VentANG +
##     VentMOD:SRMH2O + VentMOD:LNO2 + VentMOD:LNO + VentANG:SRMH2O +
##     VentANG:LNO2 + VentANG:LNO + SRMH2O:LNO2 + SRMH2O:LNO + LNO2:LNO
##
##                   Df Deviance    AIC
## - JOUR:LNO2        1   472669 7765.9
## - LNO2:LNO         1   472669 7765.9
## - MOCAGE:TEMPE     1   472690 7766.0
## - VentMOD:VentANG  1   472694 7766.0
## - JOUR:LNO         1   472703 7766.0
## - JOUR:TEMPE       1   472736 7766.0
## - JOUR:MOCAGE      1   472761 7766.1
## - JOUR:VentANG     1   472819 7766.2
## - JOUR:VentMOD     1   473112 7766.7
## - MOCAGE:STATION   4   476651 7766.9
## - MOCAGE:SRMH2O    1   473246 7766.9
## - VentANG:SRMH2O   1   473281 7767.0
## - VentMOD:LNO2     1   473316 7767.1
## - TEMPE:VentMOD    1   473577 7767.5
## - MOCAGE:VentANG   1   473648 7767.6
## - VentMOD:LNO      1   473649 7767.6
## - MOCAGE:VentMOD   1   473723 7767.8
## <none>                 472669 7767.9
## - STATION:LNO      4   477906 7769.1
## - VentMOD:SRMH2O   1   474897 7769.8
## - TEMPE:VentANG    1   475000 7770.0
## - VentANG:LNO2     1   475028 7770.1
## - SRMH2O:LNO2      1   475195 7770.4
## - SRMH2O:LNO       1   475338 7770.6
## - MOCAGE:LNO       1   475400 7770.7
## - STATION:VentMOD  4   478991 7771.0
## - VentANG:LNO      1   475950 7771.7
## - STATION:LNO2     4   479610 7772.1
## - MOCAGE:LNO2      1   476734 7773.0
## - TEMPE:LNO        1   476897 7773.3
## - TEMPE:LNO2       1   478489 7776.1
## - TEMPE:STATION    4   486020 7783.1
## - STATION:SRMH2O   4   488603 7787.5
## - TEMPE:SRMH2O     1   491312 7798.1
##
## Step:  AIC=7765.92
## O3obs ~ JOUR + MOCAGE + TEMPE + STATION + VentMOD + VentANG +
```

```
##     SRMH2O + LNO2 + LNO + JOUR:MOCAGE + JOUR:TEMPE + JOUR:VentMOD +
##     JOUR:VentANG + JOUR:LNO + MOCAGE:TEMPE + MOCAGE:STATION +
##     MOCAGE:VentMOD + MOCAGE:VentANG + MOCAGE:SRMH2O + MOCAGE:LNO2 +
##     MOCAGE:LNO + TEMPE:STATION + TEMPE:VentMOD + TEMPE:VentANG +
##     TEMPE:SRMH2O + TEMPE:LNO2 + TEMPE:LNO + STATION:VentMOD +
##     STATION:SRMH2O + STATION:LNO2 + STATION:LNO + VentMOD:VentANG +
##     VentMOD:SRMH2O + VentMOD:LNO2 + VentMOD:LNO + VentANG:SRMH2O +
##     VentANG:LNO2 + VentANG:LNO + SRMH2O:LNO2 + SRMH2O:LNO + LNO2:LNO
##
##                   Df Deviance    AIC
## - LNO2:LNO         1   472669 7763.9
## - MOCAGE:TEMPE     1   472690 7764.0
## - VentMOD:VentANG  1   472694 7764.0
## - JOUR:TEMPE       1   472748 7764.1
## - JOUR:VentANG     1   472820 7764.2
## - JOUR:MOCAGE      1   472959 7764.4
## - JOUR:VentMOD     1   473146 7764.8
## - MOCAGE:SRMH2O    1   473249 7764.9
## - VentANG:SRMH2O   1   473282 7765.0
## - VentMOD:LNO2     1   473343 7765.1
## - MOCAGE:STATION   4   476808 7765.2
## - TEMPE:VentMOD    1   473592 7765.5
## - VentMOD:LNO      1   473699 7765.7
## - MOCAGE:VentANG   1   473722 7765.8
## - MOCAGE:VentMOD   1   473747 7765.8
## <none>                 472669 7765.9
## - JOUR:LNO         1   473888 7766.1
## - STATION:LNO      4   478156 7767.5
## - VentMOD:SRMH2O   1   474897 7767.8
## - TEMPE:VentANG    1   475021 7768.1
## - SRMH2O:LNO2      1   475226 7768.4
## - VentANG:LNO2     1   475267 7768.5
## - SRMH2O:LNO       1   475383 7768.7
## - MOCAGE:LNO       1   475401 7768.7
## - STATION:VentMOD  4   479071 7769.1
## - VentANG:LNO      1   476275 7770.2
## - STATION:LNO2     4   479973 7770.7
## - MOCAGE:LNO2      1   476738 7771.1
## - TEMPE:LNO        1   476927 7771.4
## - TEMPE:LNO2       1   478527 7774.2
## - TEMPE:STATION    4   486020 7781.1
## - STATION:SRMH2O   4   488604 7785.5
## - TEMPE:SRMH2O     1   491567 7796.5
##
## Step:  AIC=7763.92
## O3obs ~ JOUR + MOCAGE + TEMPE + STATION + VentMOD + VentANG +
##     SRMH2O + LNO2 + LNO + JOUR:MOCAGE + JOUR:TEMPE + JOUR:VentMOD +
##     JOUR:VentANG + JOUR:LNO + MOCAGE:TEMPE + MOCAGE:STATION +
##     MOCAGE:VentMOD + MOCAGE:VentANG + MOCAGE:SRMH2O + MOCAGE:LNO2 +
##     MOCAGE:LNO + TEMPE:STATION + TEMPE:VentMOD + TEMPE:VentANG +
##     TEMPE:SRMH2O + TEMPE:LNO2 + TEMPE:LNO + STATION:VentMOD +
##     STATION:SRMH2O + STATION:LNO2 + STATION:LNO + VentMOD:VentANG +
##     VentMOD:SRMH2O + VentMOD:LNO2 + VentMOD:LNO + VentANG:SRMH2O +
##     VentANG:LNO2 + VentANG:LNO + SRMH2O:LNO2 + SRMH2O:LNO
```

```
##
##                   Df Deviance    AIC
## - MOCAGE:TEMPE     1   472690 7762.0
## - VentMOD:VentANG  1   472695 7762.0
## - JOUR:TEMPE       1   472749 7762.1
## - JOUR:VentANG     1   472820 7762.2
## - JOUR:MOCAGE      1   472961 7762.4
## - JOUR:VentMOD     1   473148 7762.8
## - MOCAGE:SRMH2O    1   473253 7763.0
## - VentANG:SRMH2O   1   473287 7763.0
## - VentMOD:LNO2     1   473375 7763.2
## - MOCAGE:STATION   4   476838 7763.2
## - TEMPE:VentMOD    1   473592 7763.5
## - MOCAGE:VentANG   1   473735 7763.8
## - VentMOD:LNO      1   473741 7763.8
## - MOCAGE:VentMOD   1   473784 7763.9
## <none>                 472669 7763.9
## - JOUR:LNO         1   473893 7764.1
## - VentMOD:SRMH2O   1   474912 7765.9
## - TEMPE:VentANG    1   475021 7766.1
## - STATION:LNO      4   478614 7766.3
## - SRMH2O:LNO2      1   475251 7766.5
## - VentANG:LNO2     1   475301 7766.5
## - SRMH2O:LNO       1   475401 7766.7
## - MOCAGE:LNO       1   475474 7766.8
## - STATION:VentMOD  4   479079 7767.1
## - VentANG:LNO      1   476335 7768.4
## - STATION:LNO2     4   480065 7768.8
## - MOCAGE:LNO2      1   476747 7769.1
## - TEMPE:LNO        1   476928 7769.4
## - TEMPE:LNO2       1   478567 7772.2
## - TEMPE:STATION    4   486031 7779.1
## - STATION:SRMH2O   4   488637 7783.6
## - TEMPE:SRMH2O     1   491576 7794.6
##
## Step:  AIC=7761.96
## O3obs ~ JOUR + MOCAGE + TEMPE + STATION + VentMOD + VentANG +
##     SRMH2O + LNO2 + LNO + JOUR:MOCAGE + JOUR:TEMPE + JOUR:VentMOD +
##     JOUR:VentANG + JOUR:LNO + MOCAGE:STATION + MOCAGE:VentMOD +
##     MOCAGE:VentANG + MOCAGE:SRMH2O + MOCAGE:LNO2 + MOCAGE:LNO +
##     TEMPE:STATION + TEMPE:VentMOD + TEMPE:VentANG + TEMPE:SRMH2O +
##     TEMPE:LNO2 + TEMPE:LNO + STATION:VentMOD + STATION:SRMH2O +
##     STATION:LNO2 + STATION:LNO + VentMOD:VentANG + VentMOD:SRMH2O +
##     VentMOD:LNO2 + VentMOD:LNO + VentANG:SRMH2O + VentANG:LNO2 +
##     VentANG:LNO + SRMH2O:LNO2 + SRMH2O:LNO
##
##                   Df Deviance    AIC
## - VentMOD:VentANG  1   472715 7760.0
## - JOUR:TEMPE       1   472776 7760.1
## - JOUR:VentANG     1   472837 7760.2
## - JOUR:MOCAGE      1   472982 7760.5
## - JOUR:VentMOD     1   473184 7760.8
## - MOCAGE:SRMH2O    1   473261 7761.0
## - VentANG:SRMH2O   1   473313 7761.1
```

```
## - VentMOD:LNO2     1   473385 7761.2
## - MOCAGE:STATION   4   476915 7761.4
## - TEMPE:VentMOD    1   473641 7761.6
## - MOCAGE:VentANG   1   473736 7761.8
## - VentMOD:LNO      1   473753 7761.8
## - MOCAGE:VentMOD   1   473784 7761.9
## <none>                 472690 7762.0
## - JOUR:LNO         1   473929 7762.1
## - VentMOD:SRMH2O   1   474935 7763.9
## - TEMPE:VentANG    1   475032 7764.1
## - STATION:LNO      4   478629 7764.3
## - SRMH2O:LNO2      1   475251 7764.5
## - VentANG:LNO2     1   475313 7764.6
## - SRMH2O:LNO       1   475401 7764.7
## - STATION:VentMOD  4   479089 7765.1
## - MOCAGE:LNO       1   475933 7765.6
## - VentANG:LNO      1   476362 7766.4
## - STATION:LNO2     4   480086 7766.9
## - MOCAGE:LNO2      1   477424 7768.2
## - TEMPE:LNO        1   482746 7777.5
## - TEMPE:STATION    4   488080 7780.6
## - STATION:SRMH2O   4   488763 7781.8
## - TEMPE:LNO2       1   488817 7787.9
## - TEMPE:SRMH2O     1   491583 7792.6
##
## Step:  AIC=7760
## O3obs ~ JOUR + MOCAGE + TEMPE + STATION + VentMOD + VentANG +
##     SRMH2O + LNO2 + LNO + JOUR:MOCAGE + JOUR:TEMPE + JOUR:VentMOD +
##     JOUR:VentANG + JOUR:LNO + MOCAGE:STATION + MOCAGE:VentMOD +
##     MOCAGE:VentANG + MOCAGE:SRMH2O + MOCAGE:LNO2 + MOCAGE:LNO +
##     TEMPE:STATION + TEMPE:VentMOD + TEMPE:VentANG + TEMPE:SRMH2O +
##     TEMPE:LNO2 + TEMPE:LNO + STATION:VentMOD + STATION:SRMH2O +
##     STATION:LNO2 + STATION:LNO + VentMOD:SRMH2O + VentMOD:LNO2 +
##     VentMOD:LNO + VentANG:SRMH2O + VentANG:LNO2 + VentANG:LNO +
##     SRMH2O:LNO2 + SRMH2O:LNO
##
##                   Df Deviance    AIC
## - JOUR:TEMPE       1   472800 7758.2
## - JOUR:VentANG     1   472853 7758.2
## - JOUR:MOCAGE      1   473010 7758.5
## - JOUR:VentMOD     1   473207 7758.9
## - MOCAGE:SRMH2O    1   473300 7759.0
## - VentANG:SRMH2O   1   473383 7759.2
## - VentMOD:LNO2     1   473419 7759.2
## - MOCAGE:STATION   4   476915 7759.4
## - TEMPE:VentMOD    1   473687 7759.7
## - MOCAGE:VentANG   1   473744 7759.8
## - VentMOD:LNO      1   473775 7759.9
## - MOCAGE:VentMOD   1   473799 7759.9
## <none>                 472715 7760.0
## - JOUR:LNO         1   473959 7760.2
## - TEMPE:VentANG    1   475033 7762.1
## - VentMOD:SRMH2O   1   475076 7762.1
## - STATION:LNO      4   478642 7762.4
```

```
## - VentANG:LNO2     1   475324 7762.6
## - SRMH2O:LNO2      1   475342 7762.6
## - SRMH2O:LNO       1   475499 7762.9
## - MOCAGE:LNO       1   475934 7763.6
## - STATION:VentMOD  4   479682 7764.2
## - VentANG:LNO      1   476366 7764.4
## - STATION:LNO2     4   480092 7764.9
## - MOCAGE:LNO2      1   477424 7766.3
## - TEMPE:LNO        1   482753 7775.5
## - TEMPE:STATION    4   488167 7778.8
## - STATION:SRMH2O   4   488833 7779.9
## - TEMPE:LNO2       1   488841 7785.9
## - TEMPE:SRMH2O     1   491610 7790.6
##
## Step:  AIC=7758.15
## O3obs ~ JOUR + MOCAGE + TEMPE + STATION + VentMOD + VentANG +
##     SRMH2O + LNO2 + LNO + JOUR:MOCAGE + JOUR:VentMOD + JOUR:VentANG +
##     JOUR:LNO + MOCAGE:STATION + MOCAGE:VentMOD + MOCAGE:VentANG +
##     MOCAGE:SRMH2O + MOCAGE:LNO2 + MOCAGE:LNO + TEMPE:STATION +
##     TEMPE:VentMOD + TEMPE:VentANG + TEMPE:SRMH2O + TEMPE:LNO2 +
##     TEMPE:LNO + STATION:VentMOD + STATION:SRMH2O + STATION:LNO2 +
##     STATION:LNO + VentMOD:SRMH2O + VentMOD:LNO2 + VentMOD:LNO +
##     VentANG:SRMH2O + VentANG:LNO2 + VentANG:LNO + SRMH2O:LNO2 +
##     SRMH2O:LNO
##
##                   Df Deviance    AIC
## - JOUR:VentANG     1   472953 7756.4
## - JOUR:VentMOD     1   473287 7757.0
## - JOUR:MOCAGE      1   473360 7757.1
## - MOCAGE:SRMH2O    1   473391 7757.2
## - VentANG:SRMH2O   1   473493 7757.4
## - VentMOD:LNO2     1   473519 7757.4
## - MOCAGE:STATION   4   476978 7757.5
## - TEMPE:VentMOD    1   473787 7757.9
## - MOCAGE:VentANG   1   473871 7758.0
## - VentMOD:LNO      1   473884 7758.1
## - MOCAGE:VentMOD   1   473914 7758.1
## <none>                 472800 7758.2
## - JOUR:LNO         1   474077 7758.4
## - TEMPE:VentANG    1   475079 7760.2
## - VentMOD:SRMH2O   1   475135 7760.3
## - STATION:LNO      4   478708 7760.5
## - VentANG:LNO2     1   475418 7760.7
## - SRMH2O:LNO2      1   475460 7760.8
## - SRMH2O:LNO       1   475626 7761.1
## - MOCAGE:LNO       1   476010 7761.8
## - STATION:VentMOD  4   479742 7762.3
## - VentANG:LNO      1   476480 7762.6
## - STATION:LNO2     4   480144 7763.0
## - MOCAGE:LNO2      1   477498 7764.4
## - TEMPE:LNO        1   483028 7774.0
## - TEMPE:STATION    4   488272 7776.9
## - STATION:SRMH2O   4   488896 7778.0
## - TEMPE:LNO2       1   489104 7784.4
```

```
## - TEMPE:SRMH2O     1   491694 7788.8
##
## Step:  AIC=7756.42
## O3obs ~ JOUR + MOCAGE + TEMPE + STATION + VentMOD + VentANG +
##     SRMH2O + LNO2 + LNO + JOUR:MOCAGE + JOUR:VentMOD + JOUR:LNO +
##     MOCAGE:STATION + MOCAGE:VentMOD + MOCAGE:VentANG + MOCAGE:SRMH2O +
##     MOCAGE:LNO2 + MOCAGE:LNO + TEMPE:STATION + TEMPE:VentMOD +
##     TEMPE:VentANG + TEMPE:SRMH2O + TEMPE:LNO2 + TEMPE:LNO + STATION:VentMOD +
##     STATION:SRMH2O + STATION:LNO2 + STATION:LNO + VentMOD:SRMH2O +
##     VentMOD:LNO2 + VentMOD:LNO + VentANG:SRMH2O + VentANG:LNO2 +
##     VentANG:LNO + SRMH2O:LNO2 + SRMH2O:LNO
##
##                    Df Deviance    AIC
## - MOCAGE:SRMH2O     1   473515 7755.4
## - JOUR:MOCAGE       1   473556 7755.5
## - JOUR:VentMOD      1   473631 7755.6
## - VentANG:SRMH2O    1   473649 7755.6
## - VentMOD:LNO2      1   473681 7755.7
## - MOCAGE:STATION    4   477177 7755.8
## - TEMPE:VentMOD     1   473958 7756.2
## - VentMOD:LNO       1   474055 7756.4
## - MOCAGE:VentMOD    1   474079 7756.4
## <none>                  472953 7756.4
## - MOCAGE:VentANG    1   474125 7756.5
## - JOUR:LNO          1   474182 7756.6
## - VentMOD:SRMH2O    1   475310 7758.6
## - TEMPE:VentANG     1   475326 7758.6
## - STATION:LNO       4   478803 7758.7
## - SRMH2O:LNO2       1   475569 7759.0
## - VentANG:LNO2      1   475617 7759.1
## - SRMH2O:LNO        1   475752 7759.3
## - MOCAGE:LNO        1   476095 7759.9
## - STATION:VentMOD   4   479862 7760.5
## - VentANG:LNO       1   476720 7761.0
## - STATION:LNO2      4   480235 7761.1
## - MOCAGE:LNO2       1   477588 7762.5
## - TEMPE:LNO         1   483206 7772.3
## - TEMPE:STATION     4   488374 7775.1
## - STATION:SRMH2O    4   489228 7776.6
## - TEMPE:LNO2        1   489314 7782.7
## - TEMPE:SRMH2O      1   491834 7787.0
##
## Step:  AIC=7755.41
## O3obs ~ JOUR + MOCAGE + TEMPE + STATION + VentMOD + VentANG +
##     SRMH2O + LNO2 + LNO + JOUR:MOCAGE + JOUR:VentMOD + JOUR:LNO +
##     MOCAGE:STATION + MOCAGE:VentMOD + MOCAGE:VentANG + MOCAGE:LNO2 +
##     MOCAGE:LNO + TEMPE:STATION + TEMPE:VentMOD + TEMPE:VentANG +
##     TEMPE:SRMH2O + TEMPE:LNO2 + TEMPE:LNO + STATION:VentMOD +
##     STATION:SRMH2O + STATION:LNO2 + STATION:LNO + VentMOD:SRMH2O +
##     VentMOD:LNO2 + VentMOD:LNO + VentANG:SRMH2O + VentANG:LNO2 +
##     VentANG:LNO + SRMH2O:LNO2 + SRMH2O:LNO
##
##                    Df Deviance    AIC
## - VentMOD:LNO2      1   474063 7754.4
```

```
## - JOUR:MOCAGE      1   474140 7754.5
## - JOUR:VentMOD     1   474210 7754.6
## - VentANG:SRMH2O   1   474373 7754.9
## - MOCAGE:VentMOD   1   474408 7755.0
## - VentMOD:LNO      1   474433 7755.0
## - TEMPE:VentMOD    1   474612 7755.3
## - MOCAGE:STATION   4   478087 7755.4
## <none>                473515 7755.4
## - JOUR:LNO         1   474687 7755.5
## - MOCAGE:VentANG   1   474801 7755.7
## - TEMPE:VentANG    1   475952 7757.7
## - VentMOD:SRMH2O   1   476024 7757.8
## - MOCAGE:LNO       1   476221 7758.2
## - STATION:LNO      4   479681 7758.2
## - VentANG:LNO2     1   476513 7758.7
## - SRMH2O:LNO       1   476624 7758.9
## - SRMH2O:LNO2      1   476710 7759.0
## - STATION:VentMOD  4   480709 7760.0
## - MOCAGE:LNO2      1   477635 7760.6
## - VentANG:LNO      1   477718 7760.8
## - STATION:LNO2     4   481181 7760.8
## - TEMPE:LNO        1   483260 7770.4
## - TEMPE:STATION    4   488903 7774.0
## - TEMPE:LNO2       1   489316 7780.7
## - TEMPE:SRMH2O     1   492962 7786.9
## - STATION:SRMH2O   4   500268 7793.1
##
## Step:  AIC=7754.37
## O3obs ~ JOUR + MOCAGE + TEMPE + STATION + VentMOD + VentANG +
##     SRMH2O + LNO2 + LNO + JOUR:MOCAGE + JOUR:VentMOD + JOUR:LNO +
##     MOCAGE:STATION + MOCAGE:VentMOD + MOCAGE:VentANG + MOCAGE:LNO2 +
##     MOCAGE:LNO + TEMPE:STATION + TEMPE:VentMOD + TEMPE:VentANG +
##     TEMPE:SRMH2O + TEMPE:LNO2 + TEMPE:LNO + STATION:VentMOD +
##     STATION:SRMH2O + STATION:LNO2 + STATION:LNO + VentMOD:SRMH2O +
##     VentMOD:LNO + VentANG:SRMH2O + VentANG:LNO2 + VentANG:LNO +
##     SRMH2O:LNO2 + SRMH2O:LNO
##
##                   Df Deviance    AIC
## - MOCAGE:VentMOD   1   474420 7753.0
## - JOUR:MOCAGE      1   474630 7753.4
## - MOCAGE:STATION   4   478114 7753.5
## - JOUR:VentMOD     1   474850 7753.8
## - VentANG:SRMH2O   1   474907 7753.9
## - TEMPE:VentMOD    1   474916 7753.9
## - JOUR:LNO         1   475108 7754.2
## - VentMOD:LNO      1   475134 7754.3
## <none>                474063 7754.4
## - MOCAGE:VentANG   1   475292 7754.5
## - STATION:LNO      4   479701 7756.2
## - TEMPE:VentANG    1   476525 7756.7
## - MOCAGE:LNO       1   476674 7756.9
## - VentANG:LNO2     1   476942 7757.4
## - VentMOD:SRMH2O   1   477121 7757.7
## - SRMH2O:LNO2      1   477303 7758.0
```

```
## - SRMH2O:LNO       1   477313 7758.1
## - STATION:LNO2     4   481184 7758.8
## - STATION:VentMOD  4   481242 7758.9
## - MOCAGE:LNO2      1   477930 7759.1
## - VentANG:LNO      1   478165 7759.5
## - TEMPE:LNO        1   483995 7769.6
## - TEMPE:STATION    4   489350 7772.8
## - TEMPE:LNO2       1   489965 7779.8
## - TEMPE:SRMH2O     1   493716 7786.2
## - STATION:SRMH2O   4   501217 7792.7
##
## Step:  AIC=7753
## O3obs ~ JOUR + MOCAGE + TEMPE + STATION + VentMOD + VentANG +
##     SRMH2O + LNO2 + LNO + JOUR:MOCAGE + JOUR:VentMOD + JOUR:LNO +
##     MOCAGE:STATION + MOCAGE:VentANG + MOCAGE:LNO2 + MOCAGE:LNO +
##     TEMPE:STATION + TEMPE:VentMOD + TEMPE:VentANG + TEMPE:SRMH2O +
##     TEMPE:LNO2 + TEMPE:LNO + STATION:VentMOD + STATION:SRMH2O +
##     STATION:LNO2 + STATION:LNO + VentMOD:SRMH2O + VentMOD:LNO +
##     VentANG:SRMH2O + VentANG:LNO2 + VentANG:LNO + SRMH2O:LNO2 +
##     SRMH2O:LNO
##
##                   Df Deviance    AIC
## - MOCAGE:STATION   4   478125 7751.5
## - JOUR:MOCAGE      1   475029 7752.1
## - JOUR:VentMOD     1   475219 7752.4
## - VentANG:SRMH2O   1   475273 7752.5
## - JOUR:LNO         1   475442 7752.8
## <none>                 474420 7753.0
## - VentMOD:LNO      1   475623 7753.1
## - MOCAGE:VentANG   1   475646 7753.1
## - TEMPE:VentMOD    1   475778 7753.4
## - STATION:LNO      4   480351 7755.3
## - TEMPE:VentANG    1   477165 7755.8
## - VentMOD:SRMH2O   1   477311 7756.1
## - VentANG:LNO2     1   477626 7756.6
## - SRMH2O:LNO2      1   477925 7757.1
## - SRMH2O:LNO       1   477945 7757.2
## - MOCAGE:LNO       1   478066 7757.4
## - STATION:VentMOD  4   481637 7757.6
## - STATION:LNO2     4   481875 7758.0
## - VentANG:LNO      1   478826 7758.7
## - MOCAGE:LNO2      1   480119 7760.9
## - TEMPE:LNO        1   485868 7770.8
## - TEMPE:STATION    4   490402 7772.6
## - TEMPE:LNO2       1   493313 7783.5
## - TEMPE:SRMH2O     1   494843 7786.1
## - STATION:SRMH2O   4   501543 7791.3
##
## Step:  AIC=7751.47
## O3obs ~ JOUR + MOCAGE + TEMPE + STATION + VentMOD + VentANG +
##     SRMH2O + LNO2 + LNO + JOUR:MOCAGE + JOUR:VentMOD + JOUR:LNO +
##     MOCAGE:VentANG + MOCAGE:LNO2 + MOCAGE:LNO + TEMPE:STATION +
##     TEMPE:VentMOD + TEMPE:VentANG + TEMPE:SRMH2O + TEMPE:LNO2 +
##     TEMPE:LNO + STATION:VentMOD + STATION:SRMH2O + STATION:LNO2 +
```

```
##     STATION:LNO + VentMOD:SRMH2O + VentMOD:LNO + VentANG:SRMH2O +
##     VentANG:LNO2 + VentANG:LNO + SRMH2O:LNO2 + SRMH2O:LNO
##
##                    Df Deviance    AIC
## - JOUR:MOCAGE       1   478645 7750.4
## - STATION:LNO       4   482173 7750.5
## - JOUR:VentMOD      1   479061 7751.1
## - JOUR:LNO          1   479062 7751.1
## <none>                  478125 7751.5
## - VentANG:SRMH2O    1   479579 7752.0
## - VentMOD:LNO       1   479797 7752.4
## - TEMPE:VentMOD     1   479997 7752.7
## - VentMOD:SRMH2O    1   480879 7754.3
## - MOCAGE:VentANG    1   480963 7754.4
## - MOCAGE:LNO        1   481164 7754.7
## - TEMPE:VentANG     1   481295 7755.0
## - SRMH2O:LNO        1   482346 7756.8
## - SRMH2O:LNO2       1   482474 7757.0
## - MOCAGE:LNO2       1   482602 7757.2
## - STATION:LNO2      4   486824 7758.5
## - STATION:VentMOD   4   487289 7759.3
## - VentANG:LNO2      1   485059 7761.5
## - VentANG:LNO       1   486898 7764.6
## - TEMPE:LNO         1   490251 7770.3
## - TEMPE:STATION     4   496113 7774.2
## - TEMPE:LNO2        1   498152 7783.6
## - TEMPE:SRMH2O      1   500214 7787.0
## - STATION:SRMH2O    4   506272 7791.1
##
## Step:  AIC=7750.38
## O3obs ~ JOUR + MOCAGE + TEMPE + STATION + VentMOD + VentANG +
##     SRMH2O + LNO2 + LNO + JOUR:VentMOD + JOUR:LNO + MOCAGE:VentANG +
##     MOCAGE:LNO2 + MOCAGE:LNO + TEMPE:STATION + TEMPE:VentMOD +
##     TEMPE:VentANG + TEMPE:SRMH2O + TEMPE:LNO2 + TEMPE:LNO + STATION:VentMOD +
##     STATION:SRMH2O + STATION:LNO2 + STATION:LNO + VentMOD:SRMH2O +
##     VentMOD:LNO + VentANG:SRMH2O + VentANG:LNO2 + VentANG:LNO +
##     SRMH2O:LNO2 + SRMH2O:LNO
##
##                    Df Deviance    AIC
## - STATION:LNO       4   482652 7749.3
## - JOUR:VentMOD      1   479540 7749.9
## - JOUR:LNO          1   479554 7750.0
## <none>                  478645 7750.4
## - VentANG:SRMH2O    1   480086 7750.9
## - VentMOD:LNO       1   480293 7751.2
## - TEMPE:VentMOD     1   480610 7751.8
## - VentMOD:SRMH2O    1   481487 7753.3
## - MOCAGE:VentANG    1   481518 7753.4
## - MOCAGE:LNO        1   481642 7753.6
## - TEMPE:VentANG     1   482038 7754.3
## - SRMH2O:LNO        1   482579 7755.2
## - SRMH2O:LNO2       1   482733 7755.5
## - MOCAGE:LNO2       1   483013 7755.9
## - STATION:LNO2      4   487315 7757.3
```

```
## - STATION:VentMOD  4   487987 7758.5
## - VentANG:LNO2     1   485765 7760.7
## - VentANG:LNO      1   487658 7763.9
## - TEMPE:LNO        1   490761 7769.2
## - TEMPE:STATION    4   496782 7773.3
## - TEMPE:LNO2       1   498798 7782.7
## - TEMPE:SRMH2O     1   500412 7785.4
## - STATION:SRMH2O   4   507052 7790.3
##
## Step:  AIC=7749.31
## O3obs ~ JOUR + MOCAGE + TEMPE + STATION + VentMOD + VentANG +
##     SRMH2O + LNO2 + LNO + JOUR:VentMOD + JOUR:LNO + MOCAGE:VentANG +
##     MOCAGE:LNO2 + MOCAGE:LNO + TEMPE:STATION + TEMPE:VentMOD +
##     TEMPE:VentANG + TEMPE:SRMH2O + TEMPE:LNO2 + TEMPE:LNO + STATION:VentMOD +
##     STATION:SRMH2O + STATION:LNO2 + VentMOD:SRMH2O + VentMOD:LNO +
##     VentANG:SRMH2O + VentANG:LNO2 + VentANG:LNO + SRMH2O:LNO2 +
##     SRMH2O:LNO
##
##                   Df Deviance    AIC
## - JOUR:LNO         1   483467 7748.7
## - VentMOD:LNO      1   483483 7748.7
## - JOUR:VentMOD     1   483554 7748.9
## - MOCAGE:LNO       1   483622 7749.0
## <none>                 482652 7749.3
## - VentANG:SRMH2O   1   484715 7750.9
## - TEMPE:VentMOD    1   484931 7751.2
## - VentMOD:SRMH2O   1   485691 7752.5
## - MOCAGE:LNO2      1   485714 7752.6
## - STATION:VentMOD  4   489557 7753.1
## - MOCAGE:VentANG   1   486770 7754.4
## - TEMPE:VentANG    1   486906 7754.6
## - SRMH2O:LNO       1   488398 7757.2
## - SRMH2O:LNO2      1   488580 7757.5
## - TEMPE:LNO        1   491617 7762.6
## - VentANG:LNO2     1   493633 7766.0
## - VentANG:LNO      1   496738 7771.2
## - STATION:LNO2     4   501398 7773.0
## - TEMPE:LNO2       1   499845 7776.4
## - TEMPE:STATION    4   506658 7781.7
## - TEMPE:SRMH2O     1   509035 7791.6
## - STATION:SRMH2O   4   513913 7793.5
##
## Step:  AIC=7748.72
## O3obs ~ JOUR + MOCAGE + TEMPE + STATION + VentMOD + VentANG +
##     SRMH2O + LNO2 + LNO + JOUR:VentMOD + MOCAGE:VentANG + MOCAGE:LNO2 +
##     MOCAGE:LNO + TEMPE:STATION + TEMPE:VentMOD + TEMPE:VentANG +
##     TEMPE:SRMH2O + TEMPE:LNO2 + TEMPE:LNO + STATION:VentMOD +
##     STATION:SRMH2O + STATION:LNO2 + VentMOD:SRMH2O + VentMOD:LNO +
##     VentANG:SRMH2O + VentANG:LNO2 + VentANG:LNO + SRMH2O:LNO2 +
##     SRMH2O:LNO
##
##                   Df Deviance    AIC
## - VentMOD:LNO      1   484219 7748.0
## - JOUR:VentMOD     1   484238 7748.0
```

```
## <none>                  483467 7748.7
## - MOCAGE:LNO       1   484693 7748.8
## - VentANG:SRMH2O   1   485359 7750.0
## - TEMPE:VentMOD    1   485726 7750.6
## - VentMOD:SRMH2O   1   486442 7751.8
## - STATION:VentMOD  4   490500 7752.7
## - MOCAGE:LNO2      1   487066 7752.9
## - MOCAGE:VentANG   1   487631 7753.9
## - TEMPE:VentANG    1   487673 7753.9
## - SRMH2O:LNO       1   488679 7755.6
## - SRMH2O:LNO2      1   488914 7756.0
## - TEMPE:LNO        1   492631 7762.3
## - VentANG:LNO2     1   494359 7765.3
## - VentANG:LNO      1   497569 7770.6
## - STATION:LNO2     4   502526 7772.9
## - TEMPE:LNO2       1   501037 7776.4
## - TEMPE:STATION    4   507555 7781.2
## - TEMPE:SRMH2O     1   509102 7789.7
## - STATION:SRMH2O   4   514404 7792.3
##
## Step:  AIC=7748.01
## O3obs ~ JOUR + MOCAGE + TEMPE + STATION + VentMOD + VentANG +
##     SRMH2O + LNO2 + LNO + JOUR:VentMOD + MOCAGE:VentANG + MOCAGE:LNO2 +
##     MOCAGE:LNO + TEMPE:STATION + TEMPE:VentMOD + TEMPE:VentANG +
##     TEMPE:SRMH2O + TEMPE:LNO2 + TEMPE:LNO + STATION:VentMOD +
##     STATION:SRMH2O + STATION:LNO2 + VentMOD:SRMH2O + VentANG:SRMH2O +
##     VentANG:LNO2 + VentANG:LNO + SRMH2O:LNO2 + SRMH2O:LNO
##
##                    Df Deviance    AIC
## - JOUR:VentMOD      1   485053 7747.4
## <none>                  484219 7748.0
## - MOCAGE:LNO        1   485726 7748.6
## - TEMPE:VentMOD     1   485999 7749.1
## - VentANG:SRMH2O    1   486126 7749.3
## - STATION:VentMOD   4   490647 7751.0
## - VentMOD:SRMH2O    1   487554 7751.7
## - MOCAGE:VentANG    1   488617 7753.5
## - TEMPE:VentANG     1   488644 7753.6
## - MOCAGE:LNO2       1   488837 7753.9
## - SRMH2O:LNO        1   489185 7754.5
## - SRMH2O:LNO2       1   489546 7755.1
## - TEMPE:LNO         1   494277 7763.1
## - VentANG:LNO2      1   496163 7766.3
## - VentANG:LNO       1   499407 7771.7
## - STATION:LNO2      4   503291 7772.2
## - TEMPE:LNO2        1   503841 7779.1
## - TEMPE:STATION     4   507606 7779.3
## - TEMPE:SRMH2O      1   509156 7787.8
## - STATION:SRMH2O    4   514926 7791.2
##
## Step:  AIC=7747.44
## O3obs ~ JOUR + MOCAGE + TEMPE + STATION + VentMOD + VentANG +
##     SRMH2O + LNO2 + LNO + MOCAGE:VentANG + MOCAGE:LNO2 + MOCAGE:LNO +
##     TEMPE:STATION + TEMPE:VentMOD + TEMPE:VentANG + TEMPE:SRMH2O +
```

```
##     TEMPE:LNO2 + TEMPE:LNO + STATION:VentMOD + STATION:SRMH2O +
##     STATION:LNO2 + VentMOD:SRMH2O + VentANG:SRMH2O + VentANG:LNO2 +
##     VentANG:LNO + SRMH2O:LNO2 + SRMH2O:LNO
##
##                   Df Deviance    AIC
## - JOUR             1   485125 7745.6
## <none>                 485053 7747.4
## - MOCAGE:LNO       1   486627 7748.1
## - TEMPE:VentMOD    1   486698 7748.3
## - VentANG:SRMH2O   1   486945 7748.7
## - STATION:VentMOD  4   491730 7750.8
## - VentMOD:SRMH2O   1   488662 7751.6
## - MOCAGE:VentANG   1   489407 7752.9
## - TEMPE:VentANG    1   489564 7753.1
## - MOCAGE:LNO2      1   489686 7753.4
## - SRMH2O:LNO       1   489877 7753.7
## - SRMH2O:LNO2      1   490191 7754.2
## - TEMPE:LNO        1   495103 7762.5
## - VentANG:LNO2     1   496851 7765.4
## - VentANG:LNO      1   500120 7770.9
## - STATION:LNO2     4   504404 7772.0
## - TEMPE:LNO2       1   504608 7778.3
## - TEMPE:STATION    4   508408 7778.6
## - TEMPE:SRMH2O     1   509979 7787.1
## - STATION:SRMH2O   4   515498 7790.1
##
## Step:  AIC=7745.56
## O3obs ~ MOCAGE + TEMPE + STATION + VentMOD + VentANG + SRMH2O +
##     LNO2 + LNO + MOCAGE:VentANG + MOCAGE:LNO2 + MOCAGE:LNO +
##     TEMPE:STATION + TEMPE:VentMOD + TEMPE:VentANG + TEMPE:SRMH2O +
##     TEMPE:LNO2 + TEMPE:LNO + STATION:VentMOD + STATION:SRMH2O +
##     STATION:LNO2 + VentMOD:SRMH2O + VentANG:SRMH2O + VentANG:LNO2 +
##     VentANG:LNO + SRMH2O:LNO2 + SRMH2O:LNO
##
##                   Df Deviance    AIC
## <none>                 485125 7745.6
## - MOCAGE:LNO       1   486722 7746.3
## - TEMPE:VentMOD    1   486786 7746.4
## - VentANG:SRMH2O   1   486995 7746.8
## - STATION:VentMOD  4   491800 7748.9
## - VentMOD:SRMH2O   1   488709 7749.7
## - MOCAGE:VentANG   1   489438 7750.9
## - TEMPE:VentANG    1   489576 7751.2
## - MOCAGE:LNO2      1   489811 7751.6
## - SRMH2O:LNO       1   489945 7751.8
## - SRMH2O:LNO2      1   490258 7752.3
## - TEMPE:LNO        1   495312 7760.9
## - VentANG:LNO2     1   496853 7763.4
## - VentANG:LNO      1   500120 7768.9
## - STATION:LNO2     4   504465 7770.1
## - TEMPE:LNO2       1   504903 7776.8
## - TEMPE:STATION    4   508588 7776.9
## - TEMPE:SRMH2O     1   509988 7785.1
## - STATION:SRMH2O   4   515529 7788.1
```

```r
# Coefficients du modèle
anova(reg.glm.step, test = "F")
```

```
## Analysis of Deviance Table
##
## Model: gaussian, link: identity
##
## Response: O3obs
##
## Terms added sequentially (first to last)
##
##
##                  Df Deviance Resid. Df Resid. Dev        F    Pr(>F)
## NULL                                831    1394332
## MOCAGE            1   469071       830     925261 763.8572 < 2.2e-16 ***
## TEMPE             1   225512       829     699749 367.2342 < 2.2e-16 ***
## STATION           4    10253       825     689496   4.1740 0.0023710 **
## VentMOD           1    14317       824     675179  23.3140 1.652e-06 ***
## VentANG           1    10356       823     664823  16.8641 4.434e-05 ***
## SRMH2O            1      245       822     664579   0.3983 0.5281601
## LNO2              1     3273       821     661306   5.3300 0.0212192 *
## LNO               1     9139       820     652167  14.8816 0.0001238 ***
## MOCAGE:VentANG    1      229       819     651938   0.3736 0.5412406
## MOCAGE:LNO2       1     1392       818     650546   2.2674 0.1325235
## MOCAGE:LNO        1     7499       817     643047  12.2115 0.0005014 ***
## TEMPE:STATION     4    10080       813     632967   4.1035 0.0026818 **
## TEMPE:VentMOD     1     3699       812     629268   6.0233 0.0143333 *
## TEMPE:VentANG     1    11807       811     617461  19.2275 1.317e-05 ***
## TEMPE:SRMH2O      1    41395       810     576066  67.4097 8.960e-16 ***
## TEMPE:LNO2        1    17789       809     558277  28.9678 9.708e-08 ***
## TEMPE:LNO         1     7007       808     551270  11.4112 0.0007658 ***
## STATION:VentMOD   4     3104       804     548166   1.2637 0.2827053
## STATION:SRMH2O    4    19622       800     528544   7.9884 2.580e-06 ***
## STATION:LNO2      4    13823       796     514721   5.6273 0.0001810 ***
## VentMOD:SRMH2O    1     1213       795     513508   1.9759 0.1602189
## VentANG:SRMH2O    1      618       794     512889   1.0069 0.3159628
## VentANG:LNO2      1     1375       793     511515   2.2388 0.1349817
## VentANG:LNO       1    21205       792     490309  34.5314 6.181e-09 ***
## SRMH2O:LNO2       1      365       791     489945   0.5941 0.4410590
## SRMH2O:LNO        1     4820       790     485125   7.8484 0.0052109 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# Comparer avec un modèle quadratique avec pénalité L1
x.mat2 <- model.matrix(O3obs ~ .^2 - 1, data = datappr)
reg.lasso2.cv <- cv.glmnet(y = datappr[, "O3obs"], x = x.mat2)
coef(reg.lasso2.cv, s = "lambda.1se")
```

Sélection de variable par régularisation L1 (LASSO)

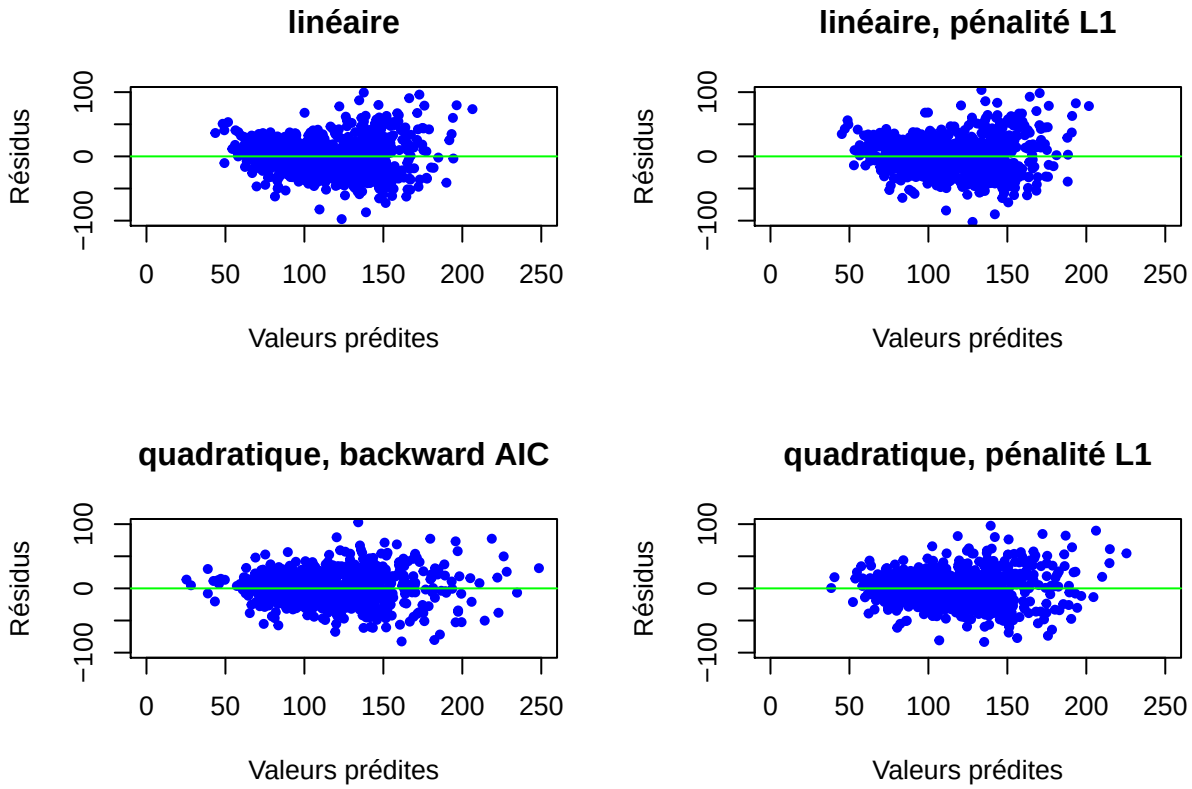
```
## 74 x 1 sparse Matrix of class "dgCMatrix"
##                               s1
## (Intercept)         34.31723669
```

```
## JOUR0                .
## JOUR1                .
## MOCAGE               .
## TEMPE                1.18775921
## STATIONAls           .
## STATIONCad           .
## STATIONPla           .
## STATIONRam           .
## VentMOD              .
## VentANG              .
## SRMH2O            -65.21915651
## LNO2                 .
## LNO                  .
## JOUR1:MOCAGE         .
## JOUR1:TEMPE          .
## JOUR1:STATIONAls     .
## JOUR1:STATIONCad     .
## JOUR1:STATIONPla     .
## JOUR1:STATIONRam     .
## JOUR1:VentMOD        .
## JOUR1:VentANG        .
## JOUR1:SRMH2O         .
## JOUR1:LNO2           .
## JOUR1:LNO            .
## MOCAGE:TEMPE         0.01254957
## MOCAGE:STATIONAls    .
## MOCAGE:STATIONCad    .
## MOCAGE:STATIONPla    .
## MOCAGE:STATIONRam    .
## MOCAGE:VentMOD       .
## MOCAGE:VentANG       .
## MOCAGE:SRMH2O        .
## MOCAGE:LNO2          .
## MOCAGE:LNO           .
## TEMPE:STATIONAls     .
## TEMPE:STATIONCad     .
## TEMPE:STATIONPla     .
## TEMPE:STATIONRam     .
## TEMPE:VentMOD        .
## TEMPE:VentANG        0.10849931
## TEMPE:SRMH2O         8.57212565
## TEMPE:LNO2           .
## TEMPE:LNO            .
## STATIONAls:VentMOD   .
## STATIONCad:VentMOD   .
## STATIONPla:VentMOD   .
## STATIONRam:VentMOD   .
## STATIONAls:VentANG   .
## STATIONCad:VentANG   2.96070272
## STATIONPla:VentANG   .
## STATIONRam:VentANG   .
## STATIONAls:SRMH2O  -26.32370987
## STATIONCad:SRMH2O    .
## STATIONPla:SRMH2O  125.41844126
```

```
## STATIONRam:SRMH2O    .
## STATIONAls:LNO2      .
## STATIONCad:LNO2      5.05292627
## STATIONPla:LNO2      .
## STATIONRam:LNO2      .
## STATIONAls:LNO       .
## STATIONCad:LNO       0.31372354
## STATIONPla:LNO       .
## STATIONRam:LNO       4.26392569
## VentMOD:VentANG      0.22677821
## VentMOD:SRMH2O      -5.53985746
## VentMOD:LNO2         .
## VentMOD:LNO          0.02470119
## VentANG:SRMH2O       .
## VentANG:LNO2         .
## VentANG:LNO          .
## SRMH2O:LNO2          .
## SRMH2O:LNO           .
## LNO2:LNO             .
```

```r
# Extraction des valeurs ajustées et des résidus
fit.glm <- reg.glm.step$fitted.values
res.glm <- reg.glm.step$residuals
fit.lasso2 <- predict(reg.lasso2.cv, s = "lambda.min", newx = x.mat2)
res.lasso2 <- dataappr$O3obs - fit.lasso2

# Graphe des résidus
options(repr.plot.width = 8, repr.plot.height = 8)
par(mfrow = c(2, 2))
plot.res(fit.lm, res.lm, "linéaire")
plot.res(fit.lasso, res.lasso, "linéaire, pénalité L1")
plot.res(fit.glm, res.glm, "quadratique, backward AIC")
plot.res(fit.lasso2, res.lasso2, "quadratique, pénalité L1")
```



Prévision de l'échantillon test

```
# Calcul des prévisions pour le nomdèle quadratique backward AIC
pred.glm <- predict(reg.glm.step, newdata = datestr)
# Erreur quadratique moyenne de prévision (MSE)
sum((pred.glm - datestr[, "O3obs"])^2) / nrow(datestr)
```

Erreur de régression

```
## [1] 601.5874
```

```
# Erreur quadratique par MOCAGE
sum((datestr[,"MOCAGE"] - datestr[,"O3obs"])^2) / nrow(datestr)
```

```
## [1] 1384.503
```

```
# Matrice de confusion pour la prévision du dépassement de seuil
table(pred.glm > 150, datestr[, "O3obs"] > 150)
```

Erreur de classification (matrice de confusion)

```
##
##         FALSE TRUE
##   FALSE   161   19
##   TRUE      5   24
```

```
# Matrice de confusion pour la prévision du
# dépassement de seuil par MOCAGE
table(datestr[, "MOCAGE"] > 150, datestr[, "O3obs"] > 150)
```

```
##
##         FALSE TRUE
##   FALSE   141   19
##   TRUE     25   24
```

-> Noter ces erreurs pour les comparer avec celles obtenues par les autres méthodes. Noter l'asymétrie des erreurs.

Prévision par modèle binomial

Plutôt que de prévoir la concentration puis le dépassement, on peut se poser la question de savoir s'il ne serait pas pertinent de prévoir directement la présence ou l'absence d'un dépassement. La variable à modéliser étant binaire, c'est la régression logistique qui va être employée. Comme pour la régression, différentes stratégies de choix de modèle peuvent être utilisées et comparées avant d'estimer l'erreur de prévision sur l'échantillon test.

```
# estimation du modèle complet
log.lm <- glm(DepSeuil ~. , data = datappq, family = binomial)
# significativité des paramètres
anova(log.lm, test = "Chisq")
```

Régression logistique sans interaction

```
## Analysis of Deviance Table
##
## Model: binomial, link: logit
##
## Response: DepSeuil
##
## Terms added sequentially (first to last)
##
##
##         Df Deviance Resid. Df Resid. Dev  Pr(>Chi)
## NULL                      831     737.81
## JOUR     1    0.444       830     737.37 0.5050277
## MOCAGE   1  125.217       829     612.15 < 2.2e-16 ***
## TEMPE    1  136.842       828     475.31 < 2.2e-16 ***
## STATION  4   16.989       824     458.32 0.0019424 **
## VentMOD  1   11.786       823     446.54 0.0005968 ***
## VentANG  1    0.837       822     445.70 0.3601454
## SRMH2O   1    6.412       821     439.29 0.0113351 *
## LNO2     1    0.189       820     439.10 0.6634989
## LNO      1    5.378       819     433.72 0.0203939 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
# Recherche d'un modèle optimal au sens d'Akaïke
log.lm.step <- step(log.lm, direction = "backward")
```

```
## Start:  AIC=459.72
## DepSeuil ~ JOUR + MOCAGE + TEMPE + STATION + VentMOD + VentANG +
##     SRMH2O + LNO2 + LNO
##
##           Df Deviance    AIC
## - MOCAGE   1   434.25 458.25
## - JOUR     1   434.36 458.36
```

```
## - VentANG  1   434.60 458.60
## <none>         433.72 459.72
## - LNO      1   439.10 463.10
## - LNO2     1   439.21 463.21
## - SRMH2O   1   440.49 464.49
## - VentMOD  1   440.90 464.90
## - STATION  4   455.47 473.47
## - TEMPE    1   550.99 574.99
##
## Step:  AIC=458.25
## DepSeuil ~ JOUR + TEMPE + STATION + VentMOD + VentANG + SRMH2O +
##     LNO2 + LNO
##
##           Df Deviance    AIC
## - JOUR     1   434.79 456.79
## - VentANG  1   435.23 457.23
## <none>         434.25 458.25
## - SRMH2O   1   441.49 463.49
## - VentMOD  1   442.86 464.86
## - LNO      1   447.00 469.00
## - LNO2     1   451.13 473.13
## - STATION  4   471.33 487.33
## - TEMPE    1   558.59 580.59
##
## Step:  AIC=456.79
## DepSeuil ~ TEMPE + STATION + VentMOD + VentANG + SRMH2O + LNO2 +
##     LNO
##
##           Df Deviance    AIC
## - VentANG  1   436.01 456.01
## <none>         434.79 456.79
## - SRMH2O   1   442.19 462.19
## - VentMOD  1   443.47 463.47
## - LNO      1   447.38 467.38
## - LNO2     1   451.41 471.41
## - STATION  4   472.00 486.00
## - TEMPE    1   559.99 579.99
##
## Step:  AIC=456.01
## DepSeuil ~ TEMPE + STATION + VentMOD + SRMH2O + LNO2 + LNO
##
##           Df Deviance    AIC
## <none>         436.01 456.01
## - SRMH2O   1   443.83 461.83
## - VentMOD  1   446.97 464.97
## - LNO      1   448.16 466.16
## - LNO2     1   452.55 470.55
## - STATION  4   475.30 487.30
## - TEMPE    1   565.19 583.19
```

```r
# Modèle obtenu
anova(log.lm.step, test = "Chisq")
```

```
## Analysis of Deviance Table
##
```

```
## Model: binomial, link: logit
##
## Response: DepSeuil
##
## Terms added sequentially (first to last)
##
##
##         Df Deviance Resid. Df Resid. Dev  Pr(>Chi)
## NULL                      831     737.81
## TEMPE    1  214.189       830     523.63 < 2.2e-16 ***
## STATION  4   32.316       826     491.31 1.649e-06 ***
## VentMOD  1   29.015       825     462.29 7.181e-08 ***
## SRMH2O   1    9.117       824     453.18 0.0025328 **
## LNO2     1    5.017       823     448.16 0.0250968 *
## LNO      1   12.151       822     436.01 0.0004907 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
# matrice de confusion de l'échantillon d'apprentissage et erreur apparente
table(log.lm.step$fitted.values > 0.5, datappq[, "DepSeuil"])
```

```
##
##         FALSE TRUE
##   FALSE   673   70
##   TRUE     24   65
```

Régression logistique avec interactions Avec autant de variables et d'interactions donc de paramètres, l'estimation du modèle complet de régression logistique rencontre des soucis et affiche des warnings car certaines probabilité trop bien ajustés (0 ou 1) provoquent des divisions par 0. Ici une procédure forward ou mieux stepwise de sélection des variables et interactions conduit à des résultats raisonnables. Une méthode avec pénalisation L1 peut aussi être utilisée.

```
# régression avec le modèle minimum
log.qm <- glm(DepSeuil ~ 1, data = datappq,family = binomial)
# algorithme stepwise en précisant le plus grand
# modèle possible
log.qm.step1 <- step(log.qm, direction = "both",
    scope = list(lower = ~1, upper = ~(JOUR + MOCAGE + TEMPE +
            STATION + VentMOD + VentANG + LNO2 + LNO + SRMH2O)^2),
    family=binomial)
```

```
## Start:  AIC=739.81
## DepSeuil ~ 1
##
##           Df Deviance    AIC
## + TEMPE    1   523.63 527.63
## + MOCAGE   1   613.24 617.24
## + SRMH2O   1   683.87 687.87
## + VentANG  1   726.72 730.72
## + STATION  4   721.68 731.68
## + LNO2     1   727.76 731.76
## + VentMOD  1   733.38 737.38
## <none>         737.81 739.81
## + LNO      1   736.47 740.47
## + JOUR     1   737.37 741.37
```

```
##
## Step:  AIC=527.63
## DepSeuil ~ TEMPE
##
##           Df Deviance    AIC
## + MOCAGE   1   476.67 482.67
## + STATION  4   491.31 503.31
## + SRMH2O   1   503.12 509.12
## + VentMOD  1   515.31 521.31
## + VentANG  1   516.54 522.54
## <none>         523.63 527.63
## + LNO      1   521.92 527.92
## + JOUR     1   522.78 528.78
## + LNO2     1   523.06 529.06
## - TEMPE    1   737.81 739.81
##
## Step:  AIC=482.67
## DepSeuil ~ TEMPE + MOCAGE
##
##                Df Deviance    AIC
## + SRMH2O        1   465.50 473.50
## + STATION       4   460.11 474.11
## + LNO           1   470.23 478.23
## + LNO2          1   471.61 479.61
## + VentMOD       1   473.42 481.42
## + VentANG       1   473.55 481.55
## <none>              476.67 482.67
## + JOUR          1   475.31 483.31
## + MOCAGE:TEMPE  1   475.40 483.40
## - MOCAGE        1   523.63 527.63
## - TEMPE         1   613.24 617.24
##
## Step:  AIC=473.5
## DepSeuil ~ TEMPE + MOCAGE + SRMH2O
##
##                 Df Deviance    AIC
## + STATION        4   449.57 465.57
## + LNO            1   460.12 470.12
## + LNO2           1   461.24 471.24
## <none>               465.50 473.50
## + VentANG        1   463.54 473.54
## + MOCAGE:TEMPE   1   463.74 473.74
## + TEMPE:SRMH2O   1   464.07 474.07
## + JOUR           1   464.25 474.25
## + VentMOD        1   464.47 474.47
## + MOCAGE:SRMH2O  1   465.32 475.32
## - SRMH2O         1   476.67 482.67
## - MOCAGE         1   503.12 509.12
## - TEMPE          1   585.77 591.77
##
## Step:  AIC=465.57
## DepSeuil ~ TEMPE + MOCAGE + SRMH2O + STATION
##
##                   Df Deviance    AIC
```

```
## + VentMOD          1   440.89 458.89
## + STATION:SRMH2O   4   435.71 459.71
## + TEMPE:STATION    4   436.45 460.45
## + VentANG          1   447.31 465.31
## <none>                 449.57 465.57
## + JOUR             1   448.13 466.13
## + TEMPE:SRMH2O     1   448.45 466.45
## + LNO              1   449.12 467.12
## + MOCAGE:TEMPE     1   449.40 467.40
## + MOCAGE:SRMH2O    1   449.47 467.47
## + LNO2             1   449.57 467.57
## + MOCAGE:STATION   4   444.97 468.97
## - STATION          4   465.50 473.50
## - SRMH2O           1   460.11 474.11
## - MOCAGE           1   471.95 485.95
## - TEMPE            1   568.69 582.69
##
## Step:  AIC=458.89
## DepSeuil ~ TEMPE + MOCAGE + SRMH2O + STATION + VentMOD
##
##                    Df Deviance    AIC
## + VentMOD:SRMH2O    1   433.12 453.12
## + STATION:SRMH2O    4   428.25 454.25
## + TEMPE:STATION     4   429.21 455.21
## + MOCAGE:VentMOD    1   437.86 457.86
## <none>                  440.89 458.89
## + TEMPE:SRMH2O      1   439.14 459.14
## + TEMPE:VentMOD     1   439.52 459.52
## + STATION:VentMOD   4   433.72 459.72
## + JOUR              1   439.89 459.89
## + VentANG           1   440.05 460.05
## + LNO2              1   440.61 460.61
## + MOCAGE:STATION    4   434.82 460.82
## + MOCAGE:SRMH2O     1   440.85 460.85
## + LNO               1   440.87 460.87
## + MOCAGE:TEMPE      1   440.89 460.89
## - SRMH2O            1   447.78 463.78
## - VentMOD           1   449.57 465.57
## - MOCAGE            1   453.18 469.18
## - STATION           4   464.47 474.47
## - TEMPE             1   568.67 584.67
##
## Step:  AIC=453.12
## DepSeuil ~ TEMPE + MOCAGE + SRMH2O + STATION + VentMOD + SRMH2O:VentMOD
##
##                    Df Deviance    AIC
## + TEMPE:STATION     4   420.27 448.27
## <none>                  433.12 453.12
## + TEMPE:VentMOD     1   431.25 453.25
## + MOCAGE:VentMOD    1   431.25 453.25
## + TEMPE:SRMH2O      1   431.30 453.30
## + JOUR              1   432.20 454.20
## + STATION:SRMH2O    4   426.36 454.36
## + VentANG           1   432.88 454.88
```

```
## + LNO2             1   432.91 454.91
## + MOCAGE:STATION   4   426.93 454.93
## + MOCAGE:SRMH2O    1   432.97 454.97
## + MOCAGE:TEMPE     1   433.06 455.06
## + LNO              1   433.09 455.09
## + STATION:VentMOD  4   427.21 455.21
## - SRMH2O:VentMOD   1   440.89 458.89
## - MOCAGE           1   443.95 461.95
## - STATION          4   456.16 468.16
## - TEMPE            1   562.80 580.80
##
## Step:  AIC=448.27
## DepSeuil ~ TEMPE + MOCAGE + SRMH2O + STATION + VentMOD + SRMH2O:VentMOD +
##     TEMPE:STATION
##
##                   Df Deviance    AIC
## + MOCAGE:VentMOD   1   416.43 446.43
## <none>                 420.27 448.27
## + STATION:SRMH2O   4   412.28 448.28
## + JOUR             1   418.96 448.96
## + TEMPE:SRMH2O     1   419.00 449.00
## + MOCAGE:STATION   4   413.75 449.75
## + LNO2             1   419.91 449.91
## + MOCAGE:TEMPE     1   420.07 450.07
## + VentANG          1   420.14 450.14
## + TEMPE:VentMOD    1   420.16 450.16
## + MOCAGE:SRMH2O    1   420.26 450.26
## + LNO              1   420.27 450.27
## + STATION:VentMOD  4   414.31 450.31
## - TEMPE:STATION    4   433.12 453.12
## - SRMH2O:VentMOD   1   429.21 455.21
## - MOCAGE           1   430.46 456.46
##
## Step:  AIC=446.43
## DepSeuil ~ TEMPE + MOCAGE + SRMH2O + STATION + VentMOD + SRMH2O:VentMOD +
##     TEMPE:STATION + MOCAGE:VentMOD
##
##                   Df Deviance    AIC
## + STATION:SRMH2O   4   407.18 445.18
## <none>                 416.43 446.43
## + MOCAGE:STATION   4   409.10 447.10
## + STATION:VentMOD  4   409.22 447.22
## + TEMPE:SRMH2O     1   415.32 447.32
## + JOUR             1   415.38 447.38
## + MOCAGE:SRMH2O    1   416.18 448.18
## + LNO              1   416.18 448.18
## + TEMPE:VentMOD    1   416.26 448.26
## - MOCAGE:VentMOD   1   420.27 448.27
## + VentANG          1   416.35 448.35
## + LNO2             1   416.42 448.42
## + MOCAGE:TEMPE     1   416.43 448.43
## - SRMH2O:VentMOD   1   423.51 451.51
## - TEMPE:STATION    4   431.25 453.25
##
```

```
## Step:  AIC=445.18
## DepSeuil ~ TEMPE + MOCAGE + SRMH2O + STATION + VentMOD + SRMH2O:VentMOD +
##     TEMPE:STATION + MOCAGE:VentMOD + SRMH2O:STATION
##
##                    Df Deviance    AIC
## + TEMPE:SRMH2O      1   400.92 440.92
## - SRMH2O:VentMOD    1   408.29 444.29
## + MOCAGE:STATION    4   399.09 445.09
## <none>                  407.18 445.18
## + JOUR              1   406.41 446.41
## - SRMH2O:STATION    4   416.43 446.43
## + LNO               1   406.91 446.91
## + MOCAGE:SRMH2O     1   407.09 447.09
## + TEMPE:VentMOD     1   407.09 447.09
## + MOCAGE:TEMPE      1   407.16 447.16
## + LNO2              1   407.17 447.17
## + VentANG           1   407.18 447.18
## + STATION:VentMOD   4   401.87 447.87
## - MOCAGE:VentMOD    1   412.28 448.28
## - TEMPE:STATION     4   423.74 453.74
##
## Step:  AIC=440.92
## DepSeuil ~ TEMPE + MOCAGE + SRMH2O + STATION + VentMOD + SRMH2O:VentMOD +
##     TEMPE:STATION + MOCAGE:VentMOD + SRMH2O:STATION + TEMPE:SRMH2O
##
##                    Df Deviance    AIC
## - SRMH2O:VentMOD    1   401.35 439.35
## + MOCAGE:STATION    4   392.59 440.59
## <none>                  400.92 440.92
## + LNO               1   400.56 442.56
## + JOUR              1   400.67 442.67
## + TEMPE:VentMOD     1   400.80 442.80
## + MOCAGE:SRMH2O     1   400.85 442.85
## + MOCAGE:TEMPE      1   400.89 442.89
## + VentANG           1   400.91 442.91
## + LNO2              1   400.91 442.91
## + STATION:VentMOD   4   395.74 443.74
## - MOCAGE:VentMOD    1   406.40 444.40
## - TEMPE:SRMH2O      1   407.18 445.18
## - SRMH2O:STATION    4   415.32 447.32
## - TEMPE:STATION     4   418.28 450.28
##
## Step:  AIC=439.35
## DepSeuil ~ TEMPE + MOCAGE + SRMH2O + STATION + VentMOD + TEMPE:STATION +
##     MOCAGE:VentMOD + SRMH2O:STATION + TEMPE:SRMH2O
##
##                    Df Deviance    AIC
## + MOCAGE:STATION    4   392.81 438.81
## <none>                  401.35 439.35
## + VentMOD:SRMH2O    1   400.92 440.92
## + LNO               1   400.99 440.99
## + JOUR              1   401.13 441.13
## + TEMPE:VentMOD     1   401.19 441.19
## + MOCAGE:SRMH2O     1   401.26 441.26
```

```
## + MOCAGE:TEMPE     1   401.31 441.31
## + VentANG          1   401.34 441.34
## + LNO2             1   401.35 441.35
## + STATION:VentMOD  4   396.44 442.44
## - MOCAGE:VentMOD   1   407.80 443.80
## - TEMPE:SRMH2O     1   408.29 444.29
## - TEMPE:STATION    4   418.74 448.74
## - SRMH2O:STATION   4   422.61 452.61
##
## Step:  AIC=438.81
## DepSeuil ~ TEMPE + MOCAGE + SRMH2O + STATION + VentMOD + TEMPE:STATION +
##     MOCAGE:VentMOD + SRMH2O:STATION + TEMPE:SRMH2O + MOCAGE:STATION
##
##                   Df Deviance    AIC
## <none>                 392.81 438.81
## + MOCAGE:TEMPE     1   390.84 438.84
## - MOCAGE:STATION   4   401.35 439.35
## + STATION:VentMOD  4   385.49 439.49
## + LNO              1   391.76 439.76
## + TEMPE:VentMOD    1   392.45 440.45
## + VentMOD:SRMH2O   1   392.59 440.59
## + LNO2             1   392.62 440.62
## + VentANG          1   392.75 440.75
## + JOUR             1   392.76 440.76
## + MOCAGE:SRMH2O    1   392.80 440.80
## - TEMPE:SRMH2O     1   399.88 443.88
## - MOCAGE:VentMOD   1   400.05 444.05
## - TEMPE:STATION    4   407.76 445.76
## - SRMH2O:STATION   4   415.01 453.01
```

```
anova(log.qm.step1, test = "Chisq")
```

```
## Analysis of Deviance Table
##
## Model: binomial, link: logit
##
## Response: DepSeuil
##
## Terms added sequentially (first to last)
##
##
##                Df Deviance Resid. Df Resid. Dev  Pr(>Chi)
## NULL                            831     737.81
## TEMPE           1  214.189       830     523.63 < 2.2e-16 ***
## MOCAGE          1   46.956       829     476.67 7.258e-12 ***
## SRMH2O          1   11.172       828     465.50 0.0008302 ***
## STATION         4   15.922       824     449.57 0.0031252 **
## VentMOD         1    8.683       823     440.89 0.0032114 **
## TEMPE:STATION   4   11.682       819     429.21 0.0198767 *
## MOCAGE:VentMOD  1    5.702       818     423.51 0.0169449 *
## SRMH2O:STATION  4   15.219       814     408.29 0.0042684 **
## TEMPE:SRMH2O    1    6.941       813     401.35 0.0084241 **
## MOCAGE:STATION  4    8.537       809     392.81 0.0737674 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# régression avec le modèle minimum
log.qm <- glm(DepSeuil ~ 1, data = datappq,family = binomial)
# algorithme stepwise en précisant le plus grand
# modèle possible
log.qm.step1 <- step(log.qm, direction = "both",
    scope = list(lower = ~1, upper = ~(JOUR + MOCAGE + TEMPE +
            STATION + VentMOD + VentANG + LNO2 + LNO + SRMH2O)^2),
    family=binomial)
```

Régression logistique avec interactions

```
## Start:  AIC=739.81
## DepSeuil ~ 1
##
##           Df Deviance    AIC
## + TEMPE    1   523.63 527.63
## + MOCAGE   1   613.24 617.24
## + SRMH2O   1   683.87 687.87
## + VentANG  1   726.72 730.72
## + STATION  4   721.68 731.68
## + LNO2     1   727.76 731.76
## + VentMOD  1   733.38 737.38
## <none>         737.81 739.81
## + LNO      1   736.47 740.47
## + JOUR     1   737.37 741.37
##
## Step:  AIC=527.63
## DepSeuil ~ TEMPE
##
##           Df Deviance    AIC
## + MOCAGE   1   476.67 482.67
## + STATION  4   491.31 503.31
## + SRMH2O   1   503.12 509.12
## + VentMOD  1   515.31 521.31
## + VentANG  1   516.54 522.54
## <none>         523.63 527.63
## + LNO      1   521.92 527.92
## + JOUR     1   522.78 528.78
## + LNO2     1   523.06 529.06
## - TEMPE    1   737.81 739.81
##
## Step:  AIC=482.67
## DepSeuil ~ TEMPE + MOCAGE
##
##                Df Deviance    AIC
## + SRMH2O        1   465.50 473.50
## + STATION       4   460.11 474.11
## + LNO           1   470.23 478.23
## + LNO2          1   471.61 479.61
## + VentMOD       1   473.42 481.42
## + VentANG       1   473.55 481.55
## <none>              476.67 482.67
## + JOUR          1   475.31 483.31
```

```
## + MOCAGE:TEMPE  1   475.40 483.40
## - MOCAGE        1   523.63 527.63
## - TEMPE         1   613.24 617.24
##
## Step:  AIC=473.5
## DepSeuil ~ TEMPE + MOCAGE + SRMH2O
##
##                 Df Deviance    AIC
## + STATION        4   449.57 465.57
## + LNO            1   460.12 470.12
## + LNO2           1   461.24 471.24
## <none>               465.50 473.50
## + VentANG        1   463.54 473.54
## + MOCAGE:TEMPE   1   463.74 473.74
## + TEMPE:SRMH2O   1   464.07 474.07
## + JOUR           1   464.25 474.25
## + VentMOD        1   464.47 474.47
## + MOCAGE:SRMH2O  1   465.32 475.32
## - SRMH2O         1   476.67 482.67
## - MOCAGE         1   503.12 509.12
## - TEMPE          1   585.77 591.77
##
## Step:  AIC=465.57
## DepSeuil ~ TEMPE + MOCAGE + SRMH2O + STATION
##
##                  Df Deviance    AIC
## + VentMOD         1   440.89 458.89
## + STATION:SRMH2O  4   435.71 459.71
## + TEMPE:STATION   4   436.45 460.45
## + VentANG         1   447.31 465.31
## <none>                449.57 465.57
## + JOUR            1   448.13 466.13
## + TEMPE:SRMH2O    1   448.45 466.45
## + LNO             1   449.12 467.12
## + MOCAGE:TEMPE    1   449.40 467.40
## + MOCAGE:SRMH2O   1   449.47 467.47
## + LNO2            1   449.57 467.57
## + MOCAGE:STATION  4   444.97 468.97
## - STATION         4   465.50 473.50
## - SRMH2O          1   460.11 474.11
## - MOCAGE          1   471.95 485.95
## - TEMPE           1   568.69 582.69
##
## Step:  AIC=458.89
## DepSeuil ~ TEMPE + MOCAGE + SRMH2O + STATION + VentMOD
##
##                   Df Deviance    AIC
## + VentMOD:SRMH2O   1   433.12 453.12
## + STATION:SRMH2O   4   428.25 454.25
## + TEMPE:STATION    4   429.21 455.21
## + MOCAGE:VentMOD   1   437.86 457.86
## <none>                 440.89 458.89
## + TEMPE:SRMH2O     1   439.14 459.14
## + TEMPE:VentMOD    1   439.52 459.52
```

```
## + STATION:VentMOD  4   433.72 459.72
## + JOUR             1   439.89 459.89
## + VentANG          1   440.05 460.05
## + LNO2             1   440.61 460.61
## + MOCAGE:STATION   4   434.82 460.82
## + MOCAGE:SRMH2O    1   440.85 460.85
## + LNO              1   440.87 460.87
## + MOCAGE:TEMPE     1   440.89 460.89
## - SRMH2O           1   447.78 463.78
## - VentMOD          1   449.57 465.57
## - MOCAGE           1   453.18 469.18
## - STATION          4   464.47 474.47
## - TEMPE            1   568.67 584.67
##
## Step:  AIC=453.12
## DepSeuil ~ TEMPE + MOCAGE + SRMH2O + STATION + VentMOD + SRMH2O:VentMOD
##
##                   Df Deviance    AIC
## + TEMPE:STATION    4   420.27 448.27
## <none>                 433.12 453.12
## + TEMPE:VentMOD    1   431.25 453.25
## + MOCAGE:VentMOD   1   431.25 453.25
## + TEMPE:SRMH2O     1   431.30 453.30
## + JOUR             1   432.20 454.20
## + STATION:SRMH2O   4   426.36 454.36
## + VentANG          1   432.88 454.88
## + LNO2             1   432.91 454.91
## + MOCAGE:STATION   4   426.93 454.93
## + MOCAGE:SRMH2O    1   432.97 454.97
## + MOCAGE:TEMPE     1   433.06 455.06
## + LNO              1   433.09 455.09
## + STATION:VentMOD  4   427.21 455.21
## - SRMH2O:VentMOD   1   440.89 458.89
## - MOCAGE           1   443.95 461.95
## - STATION          4   456.16 468.16
## - TEMPE            1   562.80 580.80
##
## Step:  AIC=448.27
## DepSeuil ~ TEMPE + MOCAGE + SRMH2O + STATION + VentMOD + SRMH2O:VentMOD +
##     TEMPE:STATION
##
##                   Df Deviance    AIC
## + MOCAGE:VentMOD   1   416.43 446.43
## <none>                 420.27 448.27
## + STATION:SRMH2O   4   412.28 448.28
## + JOUR             1   418.96 448.96
## + TEMPE:SRMH2O     1   419.00 449.00
## + MOCAGE:STATION   4   413.75 449.75
## + LNO2             1   419.91 449.91
## + MOCAGE:TEMPE     1   420.07 450.07
## + VentANG          1   420.14 450.14
## + TEMPE:VentMOD    1   420.16 450.16
## + MOCAGE:SRMH2O    1   420.26 450.26
## + LNO              1   420.27 450.27
```

```
## + STATION:VentMOD  4   414.31 450.31
## - TEMPE:STATION    4   433.12 453.12
## - SRMH2O:VentMOD   1   429.21 455.21
## - MOCAGE           1   430.46 456.46
##
## Step:  AIC=446.43
## DepSeuil ~ TEMPE + MOCAGE + SRMH2O + STATION + VentMOD + SRMH2O:VentMOD +
##     TEMPE:STATION + MOCAGE:VentMOD
##
##                    Df Deviance    AIC
## + STATION:SRMH2O   4   407.18 445.18
## <none>                 416.43 446.43
## + MOCAGE:STATION   4   409.10 447.10
## + STATION:VentMOD  4   409.22 447.22
## + TEMPE:SRMH2O     1   415.32 447.32
## + JOUR             1   415.38 447.38
## + MOCAGE:SRMH2O    1   416.18 448.18
## + LNO              1   416.18 448.18
## + TEMPE:VentMOD    1   416.26 448.26
## - MOCAGE:VentMOD   1   420.27 448.27
## + VentANG          1   416.35 448.35
## + LNO2             1   416.42 448.42
## + MOCAGE:TEMPE     1   416.43 448.43
## - SRMH2O:VentMOD   1   423.51 451.51
## - TEMPE:STATION    4   431.25 453.25
##
## Step:  AIC=445.18
## DepSeuil ~ TEMPE + MOCAGE + SRMH2O + STATION + VentMOD + SRMH2O:VentMOD +
##     TEMPE:STATION + MOCAGE:VentMOD + SRMH2O:STATION
##
##                    Df Deviance    AIC
## + TEMPE:SRMH2O     1   400.92 440.92
## - SRMH2O:VentMOD   1   408.29 444.29
## + MOCAGE:STATION   4   399.09 445.09
## <none>                 407.18 445.18
## + JOUR             1   406.41 446.41
## - SRMH2O:STATION   4   416.43 446.43
## + LNO              1   406.91 446.91
## + MOCAGE:SRMH2O    1   407.09 447.09
## + TEMPE:VentMOD    1   407.09 447.09
## + MOCAGE:TEMPE     1   407.16 447.16
## + LNO2             1   407.17 447.17
## + VentANG          1   407.18 447.18
## + STATION:VentMOD  4   401.87 447.87
## - MOCAGE:VentMOD   1   412.28 448.28
## - TEMPE:STATION    4   423.74 453.74
##
## Step:  AIC=440.92
## DepSeuil ~ TEMPE + MOCAGE + SRMH2O + STATION + VentMOD + SRMH2O:VentMOD +
##     TEMPE:STATION + MOCAGE:VentMOD + SRMH2O:STATION + TEMPE:SRMH2O
##
##                    Df Deviance    AIC
## - SRMH2O:VentMOD   1   401.35 439.35
## + MOCAGE:STATION   4   392.59 440.59
```

```
## <none>                 400.92 440.92
## + LNO              1   400.56 442.56
## + JOUR             1   400.67 442.67
## + TEMPE:VentMOD    1   400.80 442.80
## + MOCAGE:SRMH2O    1   400.85 442.85
## + MOCAGE:TEMPE     1   400.89 442.89
## + VentANG          1   400.91 442.91
## + LNO2             1   400.91 442.91
## + STATION:VentMOD  4   395.74 443.74
## - MOCAGE:VentMOD   1   406.40 444.40
## - TEMPE:SRMH2O     1   407.18 445.18
## - SRMH2O:STATION   4   415.32 447.32
## - TEMPE:STATION    4   418.28 450.28
##
## Step:  AIC=439.35
## DepSeuil ~ TEMPE + MOCAGE + SRMH2O + STATION + VentMOD + TEMPE:STATION +
##     MOCAGE:VentMOD + SRMH2O:STATION + TEMPE:SRMH2O
##
##                    Df Deviance    AIC
## + MOCAGE:STATION   4   392.81 438.81
## <none>                 401.35 439.35
## + VentMOD:SRMH2O   1   400.92 440.92
## + LNO              1   400.99 440.99
## + JOUR             1   401.13 441.13
## + TEMPE:VentMOD    1   401.19 441.19
## + MOCAGE:SRMH2O    1   401.26 441.26
## + MOCAGE:TEMPE     1   401.31 441.31
## + VentANG          1   401.34 441.34
## + LNO2             1   401.35 441.35
## + STATION:VentMOD  4   396.44 442.44
## - MOCAGE:VentMOD   1   407.80 443.80
## - TEMPE:SRMH2O     1   408.29 444.29
## - TEMPE:STATION    4   418.74 448.74
## - SRMH2O:STATION   4   422.61 452.61
##
## Step:  AIC=438.81
## DepSeuil ~ TEMPE + MOCAGE + SRMH2O + STATION + VentMOD + TEMPE:STATION +
##     MOCAGE:VentMOD + SRMH2O:STATION + TEMPE:SRMH2O + MOCAGE:STATION
##
##                    Df Deviance    AIC
## <none>                 392.81 438.81
## + MOCAGE:TEMPE     1   390.84 438.84
## - MOCAGE:STATION   4   401.35 439.35
## + STATION:VentMOD  4   385.49 439.49
## + LNO              1   391.76 439.76
## + TEMPE:VentMOD    1   392.45 440.45
## + VentMOD:SRMH2O   1   392.59 440.59
## + LNO2             1   392.62 440.62
## + VentANG          1   392.75 440.75
## + JOUR             1   392.76 440.76
## + MOCAGE:SRMH2O    1   392.80 440.80
## - TEMPE:SRMH2O     1   399.88 443.88
## - MOCAGE:VentMOD   1   400.05 444.05
## - TEMPE:STATION    4   407.76 445.76
```

```
## - SRMH2O:STATION   4   415.01 453.01
```

```
anova(log.qm.step1, test = "Chisq")
```

```
## Analysis of Deviance Table
##
## Model: binomial, link: logit
##
## Response: DepSeuil
##
## Terms added sequentially (first to last)
##
##
##                Df Deviance Resid. Df Resid. Dev  Pr(>Chi)
## NULL                           831     737.81
## TEMPE           1  214.189       830     523.63 < 2.2e-16 ***
## MOCAGE          1   46.956       829     476.67 7.258e-12 ***
## SRMH2O          1   11.172       828     465.50 0.0008302 ***
## STATION         4   15.922       824     449.57 0.0031252 **
## VentMOD         1    8.683       823     440.89 0.0032114 **
## TEMPE:STATION   4   11.682       819     429.21 0.0198767 *
## MOCAGE:VentMOD  1    5.702       818     423.51 0.0169449 *
## SRMH2O:STATION  4   15.219       814     408.29 0.0042684 **
## TEMPE:SRMH2O    1    6.941       813     401.35 0.0084241 **
## MOCAGE:STATION  4    8.537       809     392.81 0.0737674 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Prévision de l'échantillon test

```
# Prévision du modèle quadratique
pred.log <- predict(log.qm.step1, newdata = datestq, type = "response")
# Matrice de confusion pour la prévision du
# dépassement de seuil
table(pred.log > 0.5, datestq[, "DepSeuil"])
```

Matrice de confusion

```
##
##         FALSE TRUE
##   FALSE   164   20
##   TRUE      2   23
```

Comparer avec l'approche précédente. Mémoriser les résultats obtenus pour comparer avec les autres méthodes.

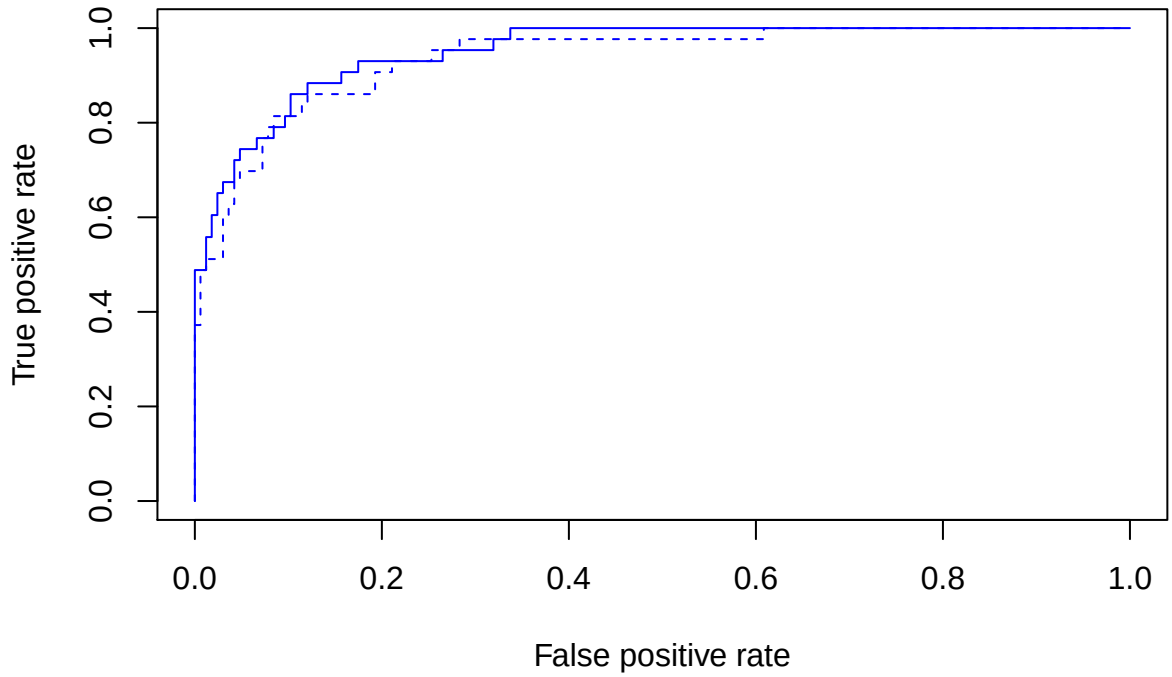
Courbe ROC

Il est également possible de construire une courbe ROC en association de la prévision obtenue à partir d'un modèle gaussien. En effet, la variation du seuil théorique de dépassement (150) va faire varier les proportions respectives des taux de vrais et faux positifs. Cela revient encore à faire varier le seuil d'une "proba" pour les valeurs de prévisions divisées par 300.

```
library(ROCR)   # Librairie à charger
roclogit <- predict(log.qm.step1, newdata = datestq, type="response")
predlogit <- prediction(roclogit, datestq[, "DepSeuil"])
```

```r
perflogit <- performance(predlogit, "tpr", "fpr")
# Tracé de la courbe
plot(perflogit, col = "blue")

# Calculs pour la régression
rocglm <- pred.glm / 300
predglm <- prediction(rocglm, datestq[, "DepSeuil"])
perfglm <- performance(predglm, "tpr", "fpr")
# tracé de la courbe et ajout au graphe précédent.
plot(perfglm, col = "blue",lty=2, add = TRUE)
```



-> Courbe ROC : La courbe ROC (receiver operating characteristic) est un graphique qui illustre la capacité de diagnostic d'un système de classification binaire lorsque son seuil de discrimination varie, cette courbe permet d'avoir la relation entre la sensibilité qui est la capacité de donné un résultat positif l'lorsque l'hypothèse est vérifié c'est le taux de vrai positif et la spécificité qui mesure sa capacité à donner un résultat négatif lorsque l'hypothèse n'est pas vérifiée (vrai négatif)).

La courbe ROC montre le compromis entre la sensibilité (ou TPR) et la spécificité (1 - FPR).

Q - Les performances des deux approches gaussiennes et binomiales sont-elles très différentes ?

Sachant que l'approche gausiennes s'est basée sur le modél linéaire et la deuxiéme approche s'est basée sur le modéle de regression logistique, on peut conclure qu'en terme de resultat de prédictions incorrectes les deux mdéles donnent approximativement les méme resultats, et donc en terme de performance les deux modéles ne sont pas vraiment differents.

Arbre de décision binaire

Q - Quel critère est optimisé lors de la création d'un noeud de l'arbre ?

-> Le critere de devision qui repose sur une fonction d'homogeneité

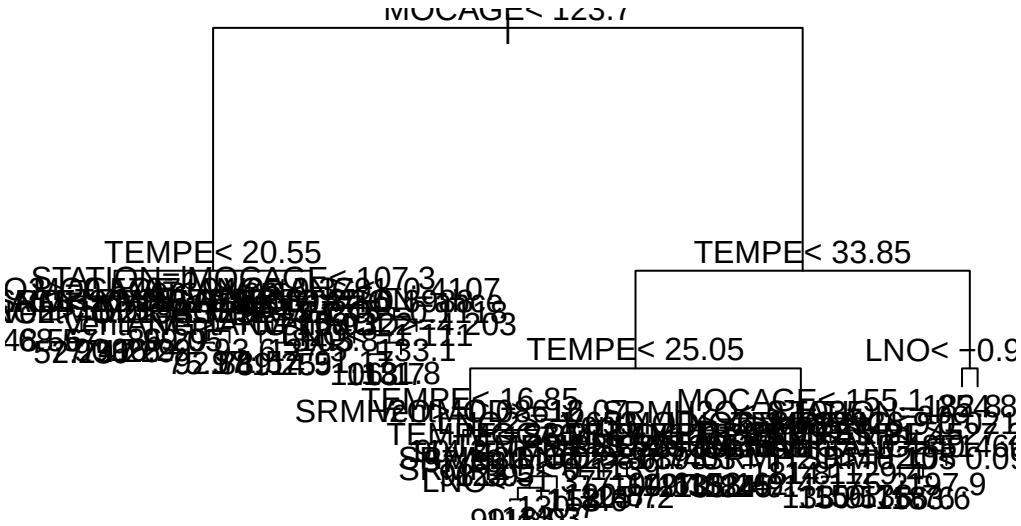
```r
library(rpart) # chargement de la librairie
tree.reg=rpart(O3obs~.,data=datappr,control=rpart.control(cp=0.001))
# La commande ci-dessous fournit un descriptif de l'arbre obtenu
```

```
# summary(tree.reg)
# mais un graphe est  préférable
```

```
library(rpart)
help(rpart)
```

```
help(rpart.control)
```

```
plot(tree.reg)
text(tree.reg)
```



L'arbre est illisible et présente trop de feuilles pour une bonne prévision (sur-apprentissage), il est nécessaire d'en réduire le nombre par élagage. Les commandes suivantes calculent les prévisions obtenues par validation croisée 10-fold pour chaque arbre élagué suivant les valeurs successives du coefficient de complexité. La séquence de ces valeurs est implicitement celle fournit par rpart.

```
xmat=xpred.rpart(tree.reg)
xerr=(xmat-datappr[,"O3obs"])^2
CVerr=apply(xerr,2,sum)
CVerr  #    CP           erreur
```

```
## 0.650389937 0.190757054 0.086599002 0.044402955 0.026636689 0.018187164
##   1398305.8    991989.8    886978.7    789240.3    754581.9    759419.5
## 0.013732509 0.011084622 0.008362540 0.007221621 0.006956881 0.006653914
##    757988.5    755639.6    757278.3    759436.5    769465.0    767974.3
## 0.006487036 0.006270700 0.005972066 0.005319037 0.004732087 0.004557061
##    770058.8    770765.7    765511.3    778117.5    776187.0    776096.0
## 0.004513292 0.004302262 0.004031475 0.003886693 0.003757776 0.003456486
##    778620.4    780091.5    772737.5    771673.8    777545.5    768463.7
## 0.002930327 0.002647561 0.002567387 0.002437882 0.002374911 0.002342909
##    773248.2    778411.5    783757.5    784177.8    784177.8    786865.4
## 0.002280352 0.002186360 0.002005132 0.001884622 0.001785959 0.001682822
##    781691.6    779093.1    777456.7    770990.6    774560.2    776474.5
## 0.001630264 0.001587103 0.001579396 0.001451242 0.001333661 0.001326259
##    777559.3    776892.0    776892.0    780687.9    785255.0    787215.6
## 0.001314821 0.001281492 0.001246655 0.001224731 0.001193056 0.001087566
##    788135.7    791273.8    794637.6    794735.0    794335.8    796230.0
## 0.001004035
##    798644.2
```

```
help(xpred.rpart)
```

Chercher la valeur de cp correspondant à la plus petite erreur puis l'utiliser la construction del'arbre.

```
as.numeric(attributes(which.min(CVerr))$names)
```

```
## [1] 0.02663669
```

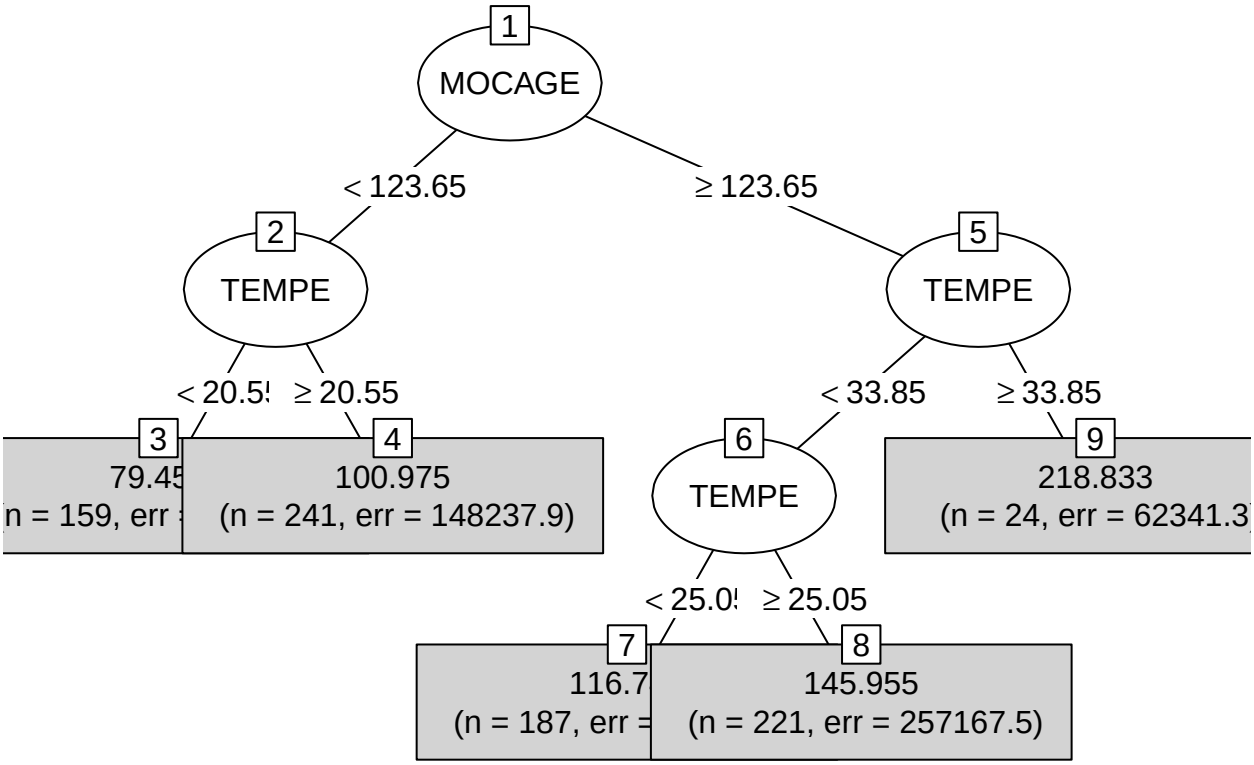
```
tree.reg=rpart(O3obs~.,data=datappr,control=rpart.control(cp=as.numeric(attributes(which.min(CVerr))$nam
```

La librairie partykit propose une construction graphique de l'arbre:

```
library(partykit)
```

```
## Loading required package: grid
## Loading required package: libcoin
## Loading required package: mvtnorm
```

```
plot(as.party(tree.reg), type="simple")
```



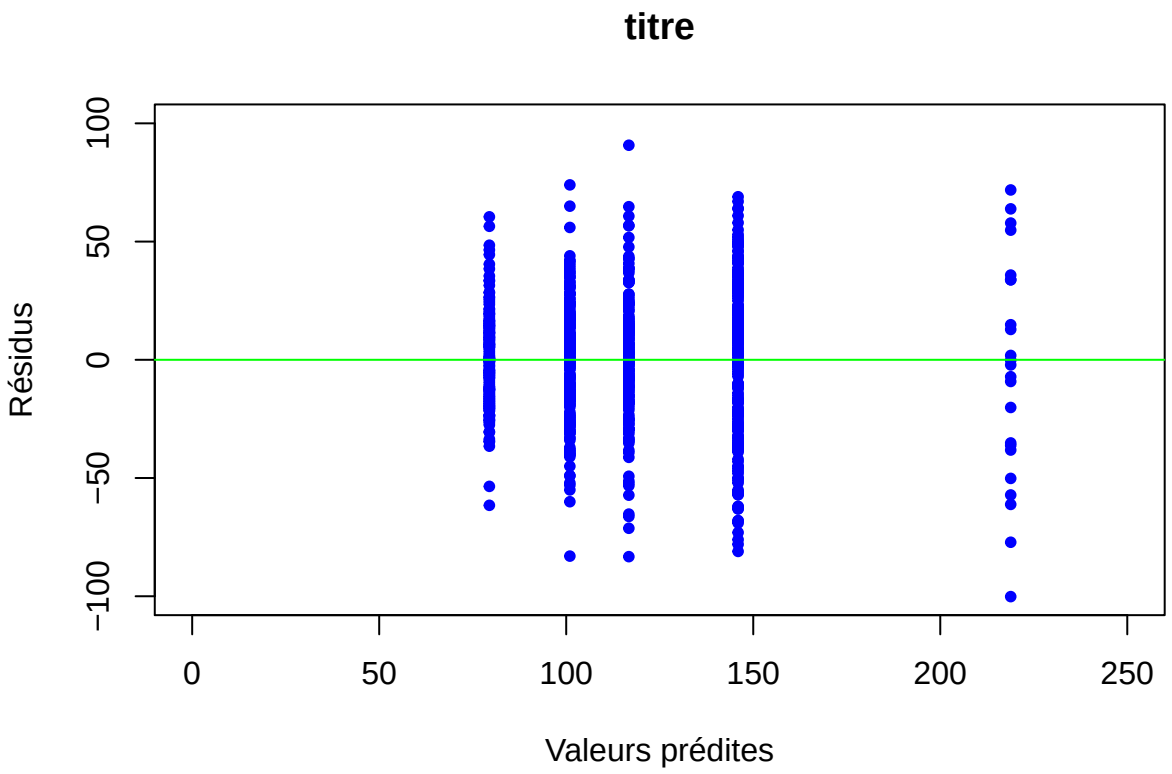
La fenêtre est trop petite pour représenter les distributions (histogramme) de la variable cible (concentration en ozone) dans chaque feuille.

Q Quelle est la variable qui contribue le plus à l'interprétation?

-> La variable de temperature.

Graphe des résidus

```
fit.tree=predict(tree.reg)
res.tree=fit.tree-datappr[,"O3obs"]
plot.res(fit.tree,res.tree)
```



Q - A quoi est due la structure particulière de ce graphe ?

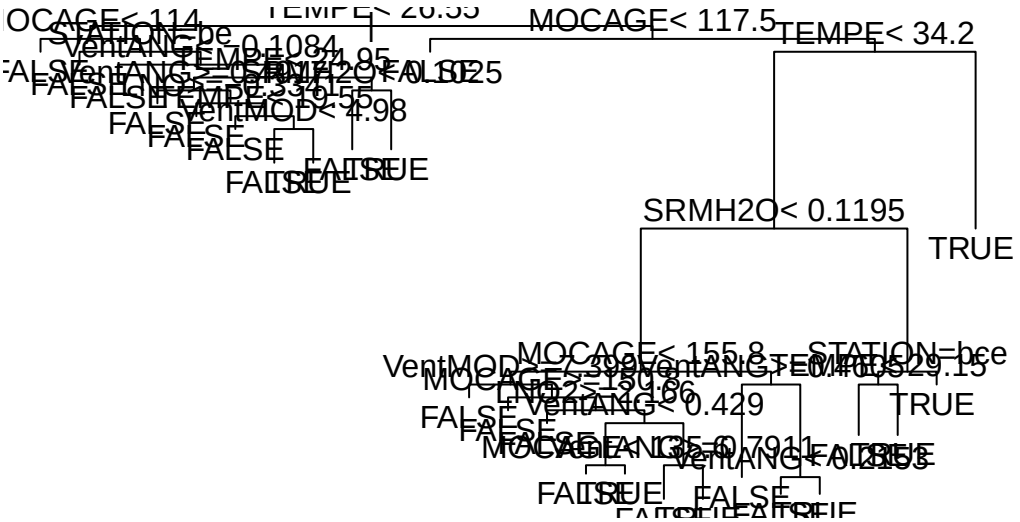
-> Par rapport aux nombres de feuilles

Estimation et élagage d'un arbre de discrimination Dans le cas d'une discrimination, le critère par défaut est l'indice de concentration de Gini ; il est possible de préciser un autre critère (split="information") ainsi que des poids sur les observations, une matrice de coûts de mauvais classement ainsi que des probabilités a priori (?rpart pour plus de détails).

Q - Quel autre critère d'hétérogénéité est utilisé ?

-> Le CP.

```
tree.dis=rpart(DepSeuil~.,data=datappq,parms=list(split="information"),cp=0.001)
plot(tree.dis)
text(tree.dis)
```



La même procédure d'élagage par validation croisée est mise en place mais avec un expression différente de l'erreur de prévision: taux de mal classés plutôt qu'erreur quadratique.

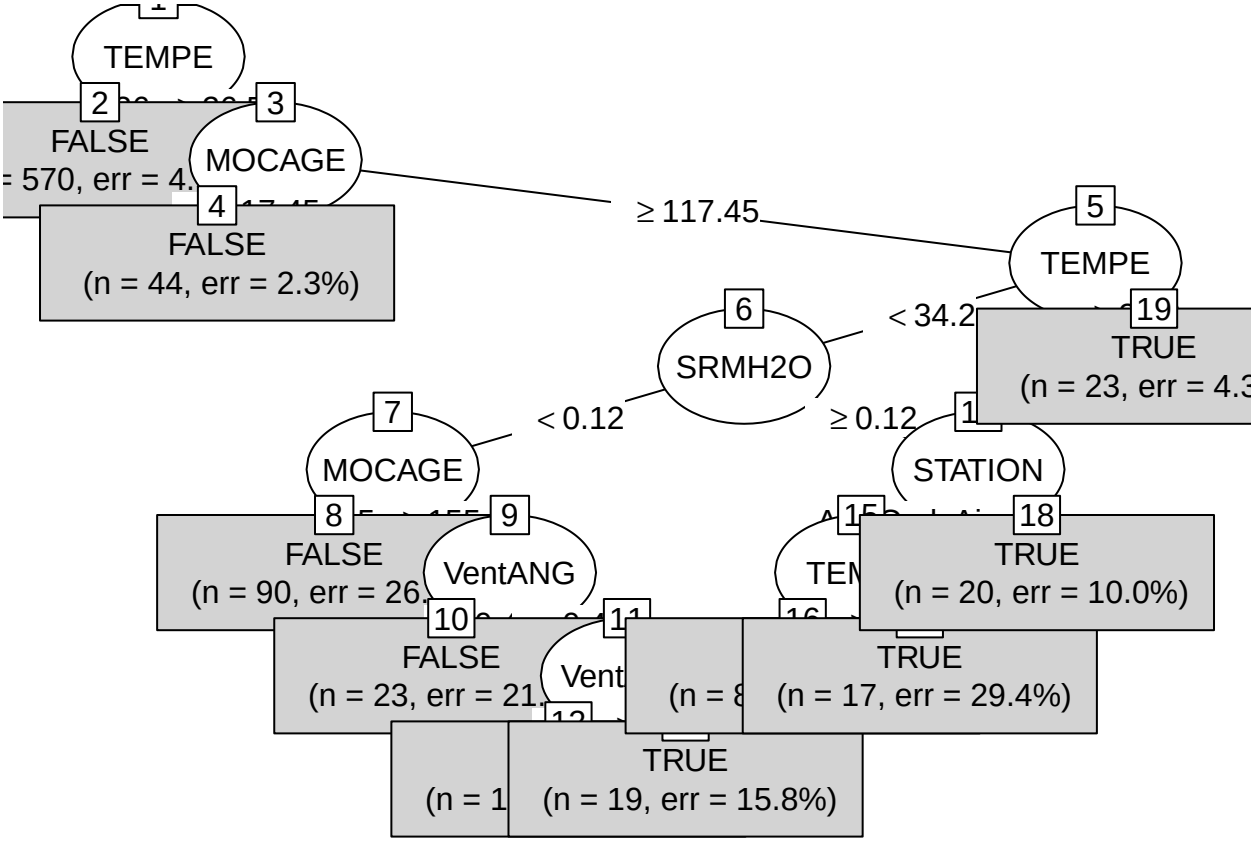
```
xmat = xpred.rpart(tree.dis)
# Comparaison des valeurs prédite et observée
xerr=datappq$DepSeuil!= (xmat>1.5)
# Calcul  des estimations des taux d'erreur
CVerr=apply(xerr, 2, sum)/nrow(xerr)
CVerr
```

```
## 0.525925926 0.045961754 0.030089031 0.018144368 0.012394963 0.009799079
##   0.1622596   0.1406250   0.1346154   0.1346154   0.1334135   0.1394231
## 0.008281733 0.002721655
##   0.1394231   0.1394231
```

```
as.numeric(attributes(which.min(CVerr))$names)
```

```
## [1] 0.01239496
```

```
tree.dis=rpart(DepSeuil~.,data=datappq,parms=list(split="information"),
               cp=as.numeric(attributes(which.min(CVerr))$names))
plot(as.party(tree.dis), type="simple")
```



Prévision de l'échantillon test

```
# Calcul des prévisions
pred.treer=predict(tree.reg,newdata=datestr)
pred.treeq=predict(tree.dis,newdata=datestq,type="class")
# Erreur quadratique moyenne de prévision en régression
sum((pred.treer-datestr[,"O3obs"])^2)/nrow(datestr)
```

Erreur de régression

```
## [1] 896.6801
```

```
# Matrice de confusion pour la prévision du
# dépassement de seuil (régression)
table(pred.treer>150,datestr[,"O3obs"]>150)
```

Erreur de classification (matrice de confusion)

```
##
##         FALSE TRUE
##   FALSE   166   38
##   TRUE      0    5
```

```
# Même chose pour l'arbre de discrimination
table(pred.treeq,datestq[,"DepSeuil"])
```

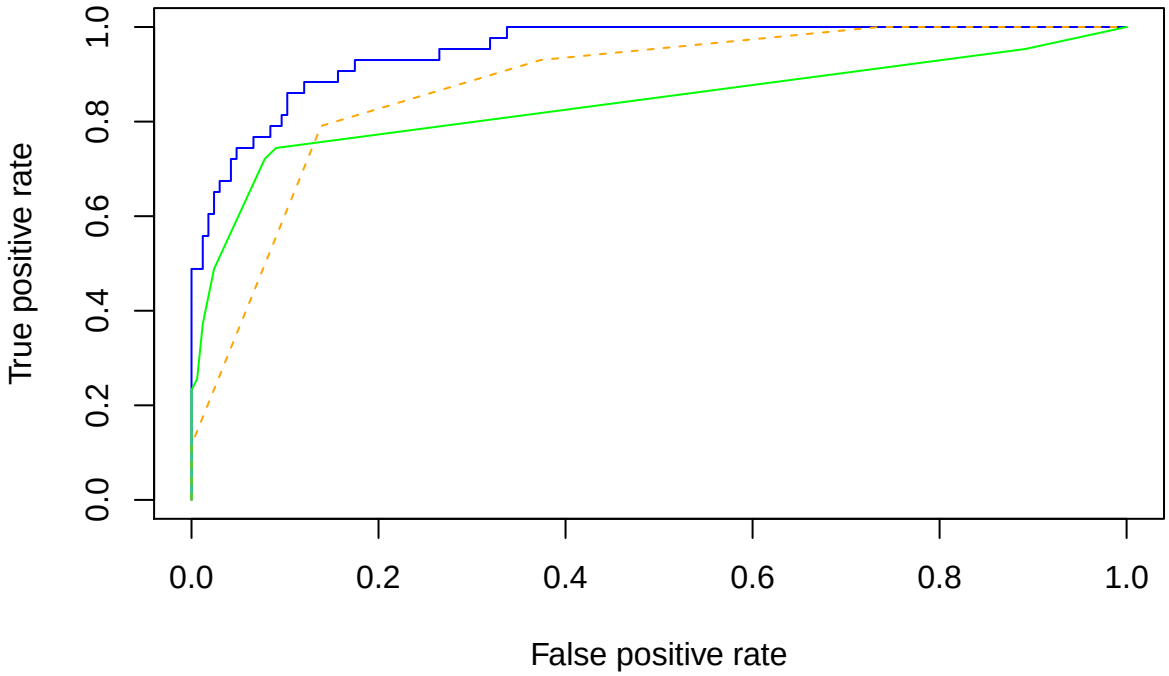
```
##
## pred.treeq FALSE TRUE
```

```
##       FALSE   164   27
##       TRUE      2   16
```

Q - Quelle stratégie semble meilleure à ce niveau ?

-> La methode de discrimination est legerment meilleurs a ce niveau.

```
ROCregtree=pred.treer/300
predregtree=prediction(ROCregtree,datestq$DepSeuil)
perfregtree=performance(predregtree,"tpr","fpr")
ROCdistree=predict(tree.dis,newdata=datestq,type="prob")[,2]
preddistree=prediction(ROCdistree,datestq$DepSeuil)
perfdistree=performance(preddistree,"tpr","fpr")
# tracer les courbes ROC en les superposant
# pour mieux comparer
plot(perflogit,col="blue")
plot(perfregtree,col="orange",lty=2,add=TRUE)
plot(perfdistree,col="green",add=TRUE)
```



Courbes ROC

Q - Une meilleure méthode se dégage-t-elle ?

-> La méthode qui represente la courbe bleu.

Réseau de neurones

Introduction

Q - Quelle fonction de transfert pour le dernier neurone en régression ?

-> C'est la fonction Linéaire (puisque c'est une régression linéaire donc notre sortie est linéaire).

Q - Quelle focntion de transfert pour le dernier neuronne en discrimination binaire ?

-> En classification binaire, le neurone de sortie est muni également de la fonction sigmoïde qui nous donne en sortie soit 0 ou 1.

Q - Quid de la discrimination avec plusieurs classes ?

-> Le cas d'une discrimination à m classes, le neurone de sortie intègre une fonction d'activation softmax à valeurs dans Rm pour avoir le resultat avec la plus grande possibilité.

Q - Quel est le choix par défaut pour les neurones de la couche cachée ?

-> Les neurones de la couche cachée sont munis de la fonction sigmoïde. Q - Quel est le paramètre decay de la fonction nnet ?

-> C'est un paramètre qui contribue à limiter le sur-apprentissage

Q - Indiquer une autre façon d'éviter le sur-apprentissage.

-> En utilisant la fonction Dropout. Le Dropout est une technique permettant de réduire l'overfitting lors de l'entraînement du modèle. Le terme » Dropout » fait référence à la suppression de neurones dans les couches d'un modèle de Deep Learning. Le choix des neurones à désactiver est aléatoire

Cas de la régression

```
library(MASS)
```

```
##
## Attaching package: 'MASS'
```

```
## The following object is masked from 'package:dplyr':
##
##     select
```

```
library(nnet)
# apprentissage
# attention au paramètre linout dans le cas de la régression
nnet.reg=nnet(O3obs~.,data=datappr,size=5,decay=1,linout=TRUE,maxit=500)
```

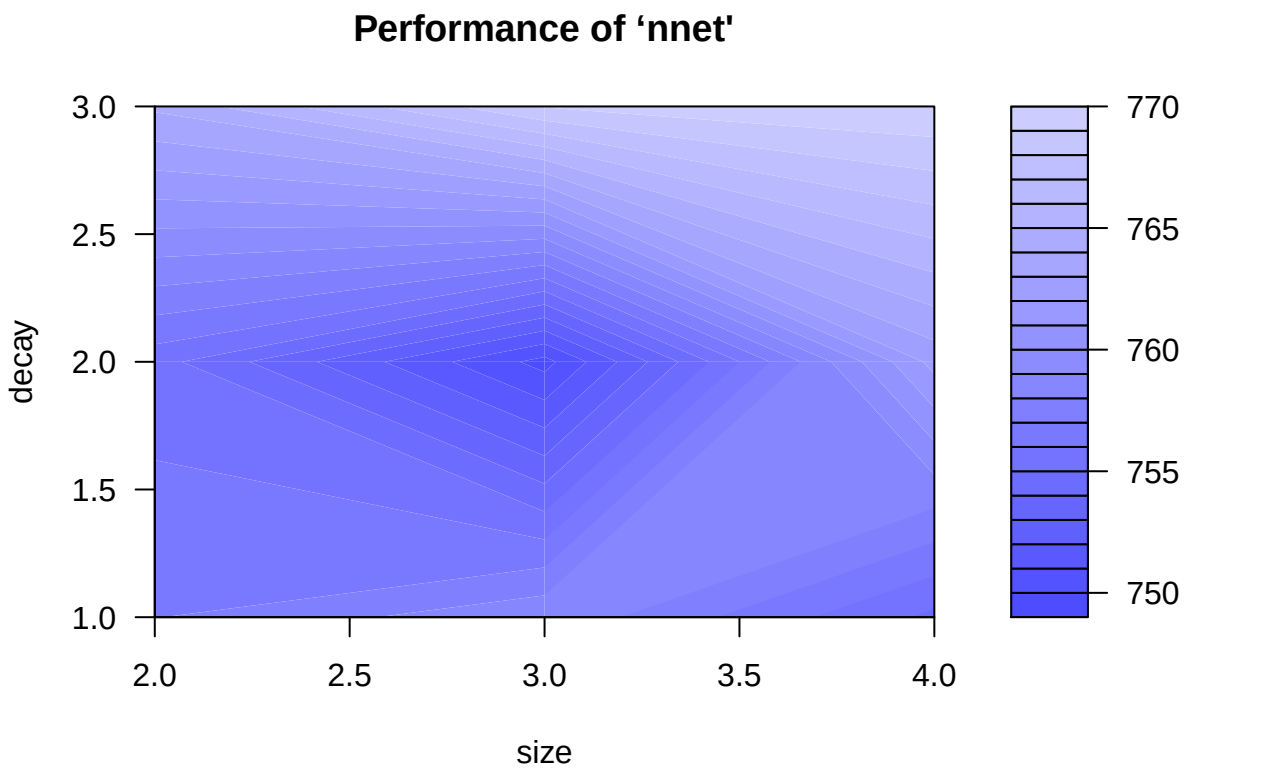
```
## # weights:  71
## initial  value 12800600.503961
## iter  10 value 1403226.715526
## iter  20 value 1378367.725197
## iter  30 value 1325985.532270
## iter  40 value 1203205.711099
## iter  50 value 1182538.402253
## iter  60 value 1009515.515525
## iter  70 value 784298.614986
## iter  80 value 726844.413549
## iter  90 value 718165.897923
## iter 100 value 687498.725231
## iter 110 value 655646.769198
## iter 120 value 628401.502474
## iter 130 value 612193.712558
## iter 140 value 596760.436963
## iter 150 value 587075.854849
## iter 160 value 555710.607187
## iter 170 value 534529.295382
## iter 180 value 532158.924977
## iter 190 value 526985.979672
## iter 200 value 521779.122183
## iter 210 value 515964.500926
## iter 220 value 513957.818575
```

```
## iter 230 value 508332.723363
## iter 240 value 502373.653528
## iter 250 value 491467.351747
## iter 260 value 484983.253943
## iter 270 value 483190.843769
## iter 280 value 481716.248812
## iter 290 value 480618.073767
## iter 300 value 479648.771105
## iter 310 value 479530.435614
## iter 320 value 479520.880382
## iter 330 value 479517.332960
## iter 340 value 479514.805718
## iter 350 value 479512.443339
## iter 360 value 479510.842679
## iter 370 value 479509.324918
## iter 380 value 479508.758279
## iter 380 value 479508.754412
## iter 380 value 479508.754412
## final  value 479508.754412
## converged
```

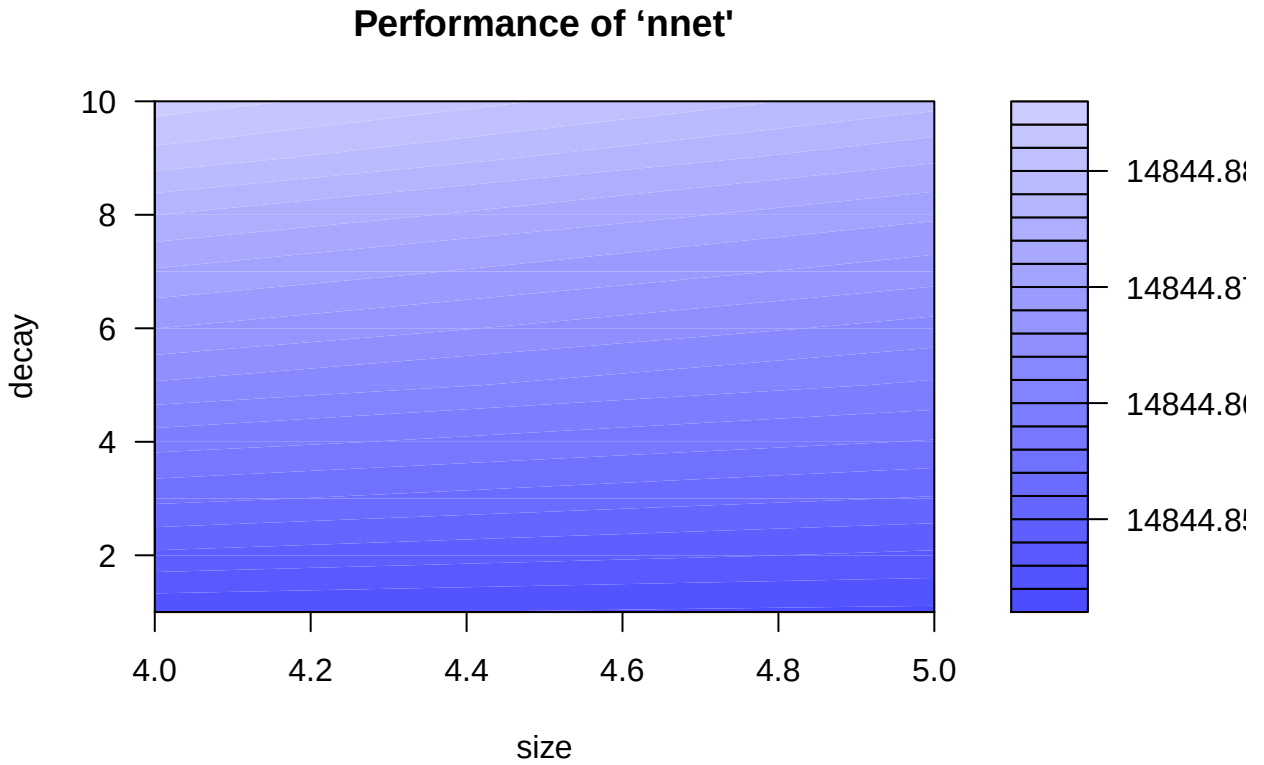
```
summary(nnet.reg)
```

```
## a 12-5-1 network with 71 weights
## options were - linear output units  decay=1
##   b->h1  i1->h1  i2->h1  i3->h1  i4->h1  i5->h1  i6->h1  i7->h1  i8->h1  i9->h1
##    0.99   -0.03    0.03    0.39   -0.26    2.19   -0.19    1.19    0.05   -0.72
## i10->h1 i11->h1 i12->h1
##  -16.25   -7.15    6.73
##   b->h2  i1->h2  i2->h2  i3->h2  i4->h2  i5->h2  i6->h2  i7->h2  i8->h2  i9->h2
##    9.37  -12.07    0.66   -0.95   -8.62  -34.56   -7.69  -24.24   -1.51   -2.25
## i10->h2 i11->h2 i12->h2
##    2.50  -13.78   17.23
##   b->h3  i1->h3  i2->h3  i3->h3  i4->h3  i5->h3  i6->h3  i7->h3  i8->h3  i9->h3
##  -22.26    1.91    0.07    0.56   -1.22    2.45    7.73   -1.27   -0.35    3.75
## i10->h3 i11->h3 i12->h3
##  -19.10    2.67   -0.40
##   b->h4  i1->h4  i2->h4  i3->h4  i4->h4  i5->h4  i6->h4  i7->h4  i8->h4  i9->h4
##   11.22   13.20    0.24   -1.85    1.44   16.62   -8.95  -10.75   -3.86    6.15
## i10->h4 i11->h4 i12->h4
##    2.88   15.73  -28.43
##   b->h5  i1->h5  i2->h5  i3->h5  i4->h5  i5->h5  i6->h5  i7->h5  i8->h5  i9->h5
##  -24.00   -0.33   -0.01    0.47    0.62    0.71    4.02   -0.63   -0.02    0.59
## i10->h5 i11->h5 i12->h5
##   29.43    3.32   -2.59
##   b->o  h1->o  h2->o  h3->o  h4->o  h5->o
##  28.81  48.20  22.32  29.58  17.72  96.02
```

```
library(e1071)
plot(tune.nnet(O3obs~.,data=datappr,size=c(2,3,4),decay=c(1,2,3),maxit=200,linout=TRUE))
```




```
plot(tune.nnet(O3obs~.,data=datappr,size=4:5,decay=1:10))
```

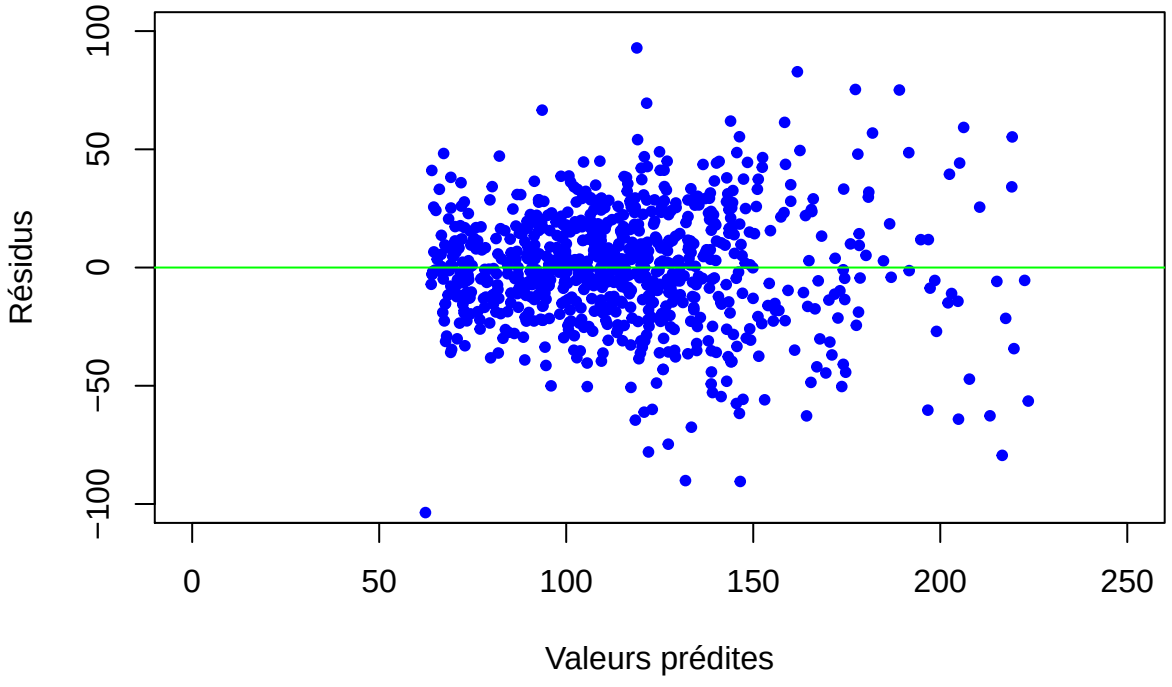



```
nnet.reg=nnet(O3obs~.,data=datappr,size=3,decay=2,linout=TRUE,maxit=200)
```

```
## # weights:  43
## initial  value 12470079.023193
```

```
## iter  10 value 1345605.086089
## iter  20 value 1166380.147153
## iter  30 value 1106454.275613
## iter  40 value 965356.560257
## iter  50 value 853350.341735
## iter  60 value 812953.775021
## iter  70 value 746215.056332
## iter  80 value 706861.780543
## iter  90 value 660807.673517
## iter 100 value 623551.412771
## iter 110 value 606733.361236
## iter 120 value 591635.527630
## iter 130 value 582967.367064
## iter 140 value 563154.546803
## iter 150 value 551060.719587
## iter 160 value 550670.709953
## iter 170 value 550476.882641
## iter 180 value 550461.033498
## final  value 550460.995397
## converged
```

```
# calcul et graphe des résidus
fit.nnetr=predict(nnet.reg,data=datappr)
res.nnetr=fit.nnetr-datappr[,"O3obs"]
plot.res(fit.nnetr,res.nnetr,titre="")
```



Cas de la discrimination

```
# apprentissage
nnet.dis=nnet(DepSeuil~.,data=datappq,size=5,decay=0)
```

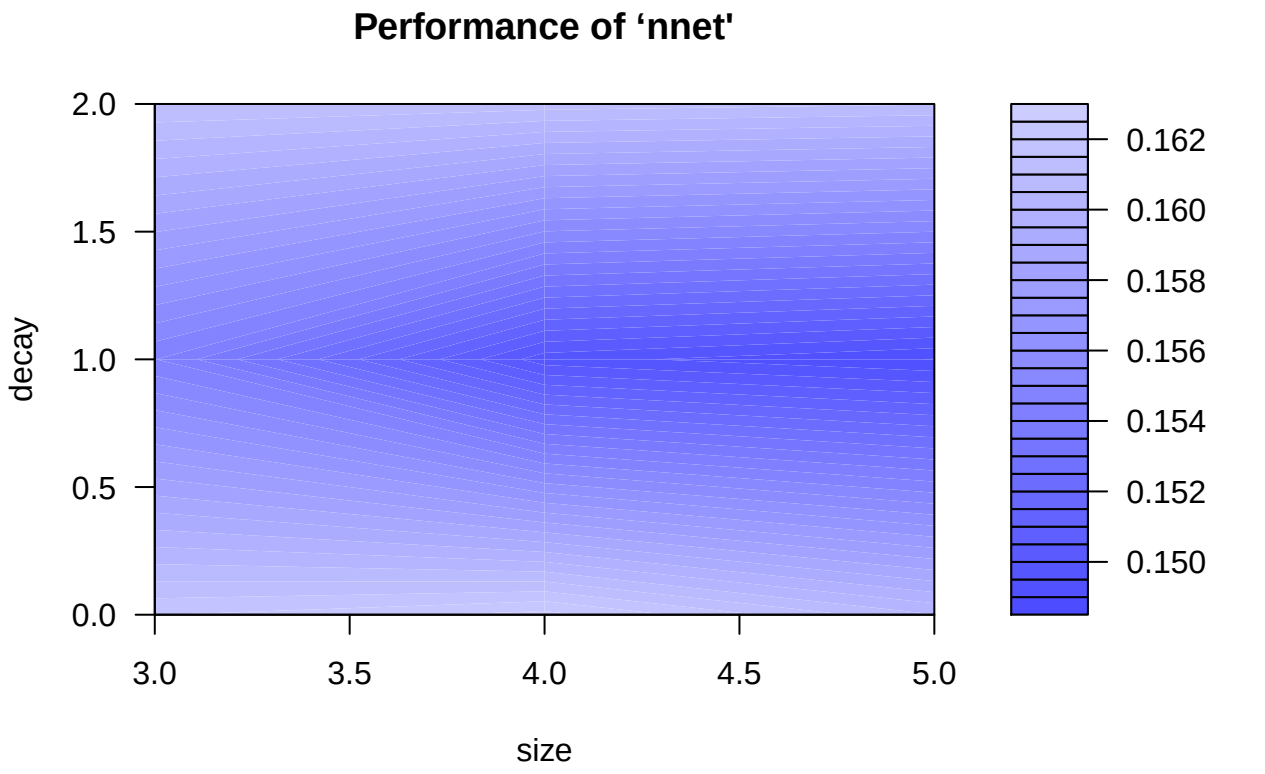
```
## # weights:  71
## initial  value 831.843502
```

```
## final  value 368.907081
## converged
```

```
summary(nnet.reg)
```

```
## a 12-3-1 network with 43 weights
## options were - linear output units  decay=2
##   b->h1  i1->h1  i2->h1  i3->h1  i4->h1  i5->h1  i6->h1  i7->h1  i8->h1  i9->h1
##   -4.23    0.04    0.07    0.16    0.23   -0.11    1.04    0.59   -0.07    0.88
## i10->h1 i11->h1 i12->h1
##  -10.76   -3.64    3.71
##   b->h2  i1->h2  i2->h2  i3->h2  i4->h2  i5->h2  i6->h2  i7->h2  i8->h2  i9->h2
##  -22.66    0.04    0.01    0.55    2.24    1.22    4.77    1.24    0.08    0.65
## i10->h2 i11->h2 i12->h2
##   20.95   -0.29    1.27
##   b->h3  i1->h3  i2->h3  i3->h3  i4->h3  i5->h3  i6->h3  i7->h3  i8->h3  i9->h3
##   14.73    1.71    0.06   -2.20    6.46  -14.47    2.27   11.75    1.98    7.56
## i10->h3 i11->h3 i12->h3
##   -0.22   10.63   -6.28
##   b->o  h1->o  h2->o  h3->o
##  84.12  60.13  80.89 -21.75
```

```
plot(tune.nnet(DepSeuil~.,data=datappq,size=c(3,4,5),decay=c(0,1,2),maxit=200,linout=FALSE))
```




```
nnet.dis=nnet(DepSeuil~.,data=datappq,size=5,decay=1)
```

```
## # weights:  71
## initial  value 528.404962
## iter  10 value 371.482110
## iter  20 value 369.595961
## iter  30 value 353.107665
```

```
## iter  40 value 315.076306
## iter  50 value 298.343924
## iter  60 value 290.984869
## iter  70 value 287.575644
## iter  80 value 279.386256
## iter  90 value 276.569665
## iter 100 value 274.937793
## final  value 274.937793
## stopped after 100 iterations
```

Prévisions de l'échantillon test

```
# Calcul des prévisions
pred.nnetr=predict(nnet.reg,newdata=datestr)
pred.nnetq=predict(nnet.dis,newdata=datestq)
# Erreur quadratique moyenne de prévision
sum((pred.nnetr-datestr[,"O3obs"])^2)/nrow(datestr)
```

Erreur de régression

```
## [1] 578.4729
```

```
# Matrice de confusion pour la prévision du dépassement de seuil (régression)
table(pred.nnetr>150,datestr[,"O3obs"]>150)
```

Erreur de classification (matrice de confusion)

```
##
##         FALSE TRUE
##   FALSE   162   19
##   TRUE      4   24
```

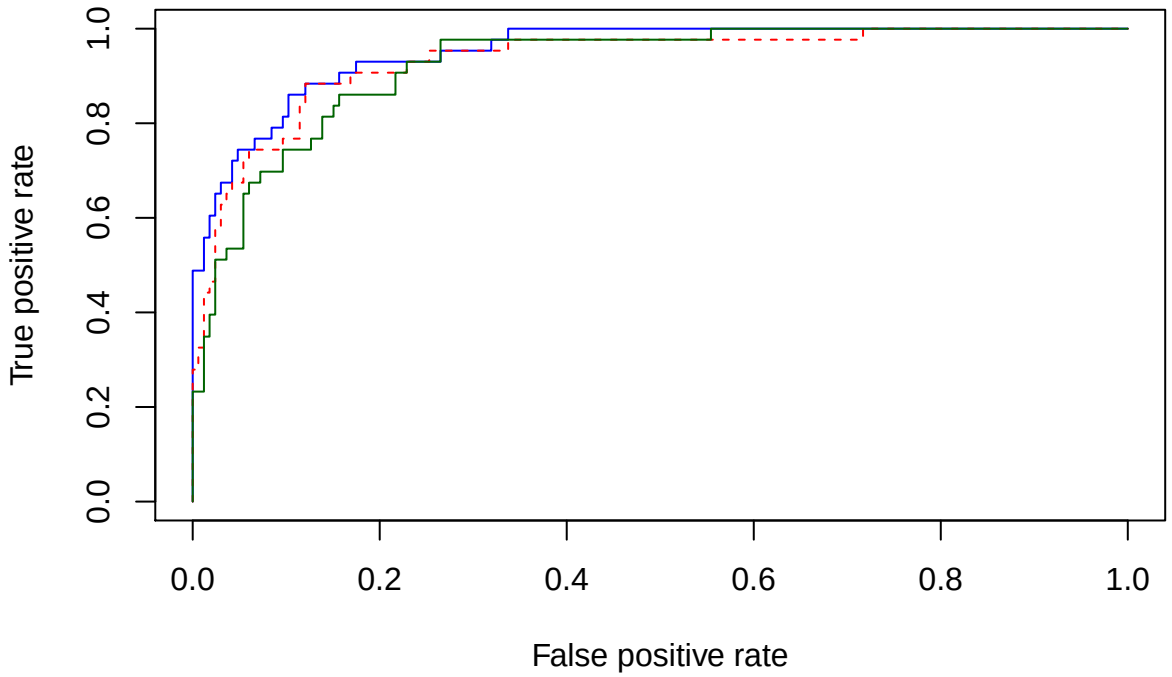
```
# Même chose pour la discrimination
table(pred.nnetq>0.5,datestq[,"DepSeuil"])
```

```
##
##         FALSE TRUE
##   FALSE   166   34
##   TRUE      0    9
```

```
library(ROCR)
rocnnetr=pred.nnetr/300
prednnetr=prediction(rocnnetr,datestq$DepSeuil)
perfnnetr=performance(prednnetr,"tpr","fpr")

rocnnetq=pred.nnetq
prednnetq=prediction(rocnnetq,datestq$DepSeuil)
perfnnetq=performance(prednnetq,"tpr","fpr")

# tracer les courbes ROC en les superposant pour mieux comparer
plot(perflogit,col="blue")           #binomial
plot(perfnnetr,col="red",lty=2,add=TRUE)  #regression lineare
plot(perfnnetq,col="darkgreen",add=TRUE)   #Discrimination
```



Courbe ROC

Q - Une méthode semble-t-elle significativement meilleure ?

Les résultats sont presque similaires mais le modèle binomial est le plus correct.