Practical 1 — River discharge & precipitation extremes (Neuchâtel)

2025-10-07

Contents

Introduction

This report reproduces the worked solution for Practical 1. It loads the daily river discharge and precipitation data for Neuchâtel, performs exploratory data analysis, fits extreme-value models (block maxima GEV for discharge and POT/GPD for precipitation), conducts a simple declustering procedure, inspects tail dependence, and runs the provided extreme causality tests from `JuroExtremes.R`.

All code here is executed; figures are embedded below and results saved to `practical_1/practical1_results.rds`.

0. Load packages and data

Methodology

This section installs/loads the R packages required for the analysis and reads the CSV data. The data is expected to be in `practical_1/River_and_precip_Neuchatel.csv`.

Results / Notes

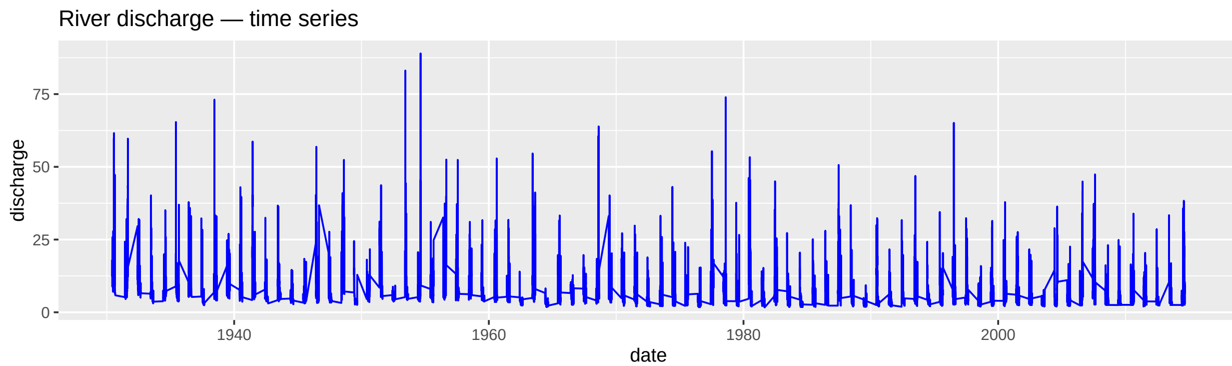
Packages will be installed if missing; the small preview table below shows the first rows of the data.

```r
required_pkgs <- c('readr','lubridate','ggplot2','dplyr','evd','ismev','forecast','knitr')
missing <- required_pkgs[!required_pkgs %in% installed.packages()[,1]]
if(length(missing)) install.packages(missing, repos = 'https://cloud.r-project.org')

library(readr); library(lubridate); library(ggplot2); library(dplyr)
library(evd); library(ismev); library(forecast)

fig_dir <- file.path('practical_1','figures')
if(!dir.exists(fig_dir)) dir.create(fig_dir, recursive = TRUE)

data_path <- file.path('practical_1','River_and_precip_Neuchatel.csv')
stopifnot(file.exists(data_path))
raw <- read_csv(data_path, col_types = cols(Date = col_date(format = "%Y-%m-%d"),
                                            RiverDischarge = col_double(),
                                            Precipitation = col_double()))

df <- raw %>% rename(date = Date, discharge = RiverDischarge, precip = Precipitation)

# basic table
kable(head(df, 6))
```

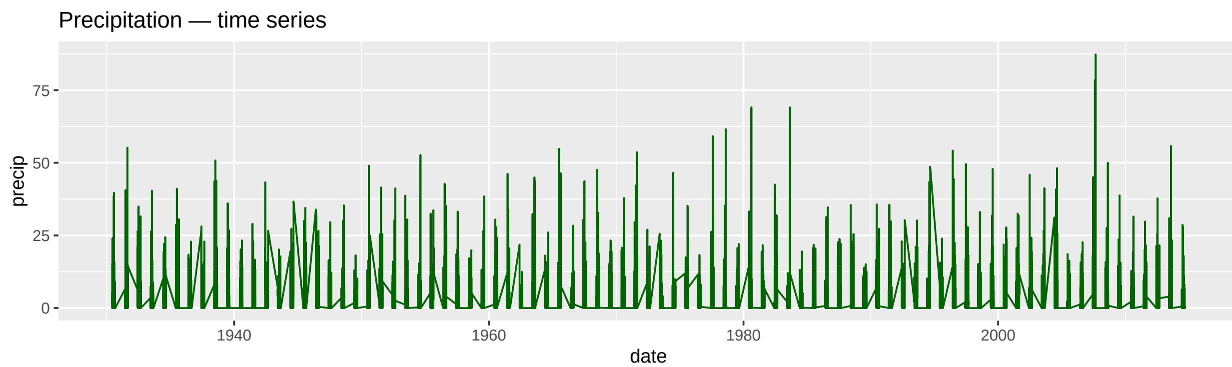
date	discharge	precip
1930-06-02	12.30	15.4
1930-06-03	14.30	0.0
1930-06-04	18.00	0.0
1930-06-05	12.10	0.0
1930-06-06	10.20	5.5
1930-06-07	8.81	1.3

1 Exploratory plots (time series + seasonality)

```r
# ggplot time series
p1 <- ggplot(df, aes(x = date, y = discharge)) + geom_line(color='blue') + labs(title='River discharge
print(p1)
```




```r
p2 <- ggplot(df, aes(x = date, y = precip)) + geom_line(color='darkgreen') + labs(title='Precipitation 
print(p2)
```



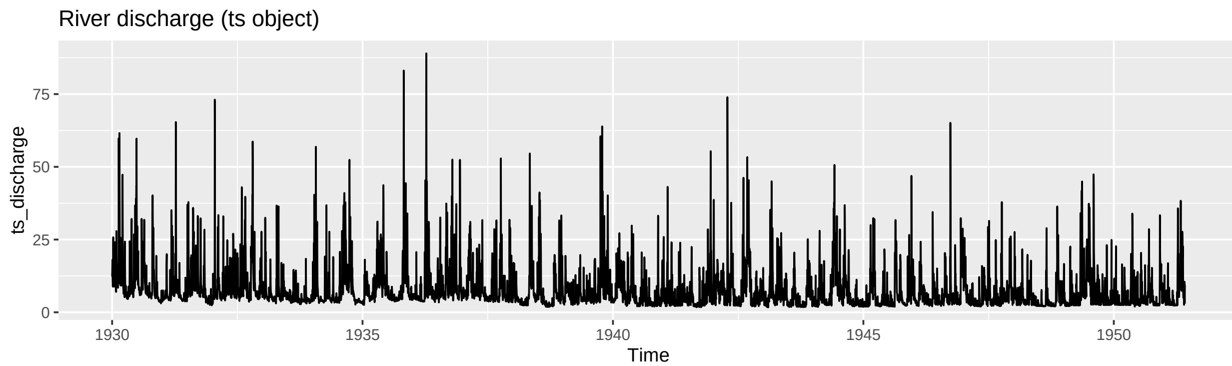
Methodology

We produce line plots of the daily series for visual inspection of trends and large events.

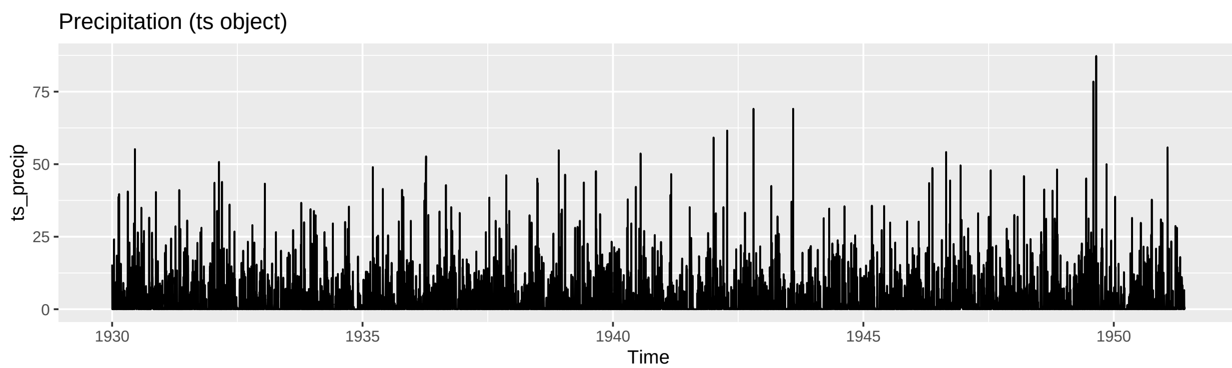
Results / Comments

The plots below highlight periods of elevated discharge and precipitation; seasonal structure is also inspected with monthly boxplots below.

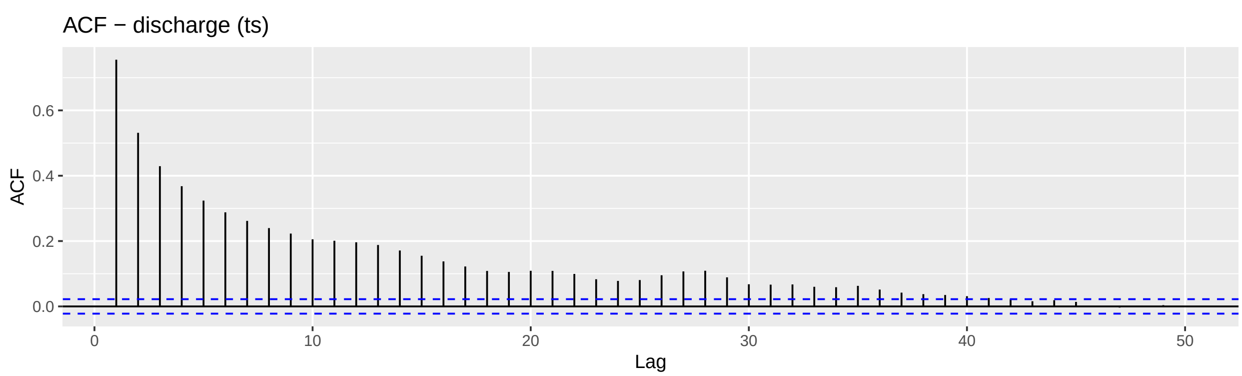
```r
# ts objects
ts_start_year <- year(min(df$date, na.rm = TRUE))
ts_discharge <- ts(df$discharge, start = c(ts_start_year,1), frequency = 365)
ts_precip <- ts(df$precip, start = c(ts_start_year,1), frequency = 365)
print(autoplot(ts_discharge) + labs(title='River discharge (ts object)'))
```



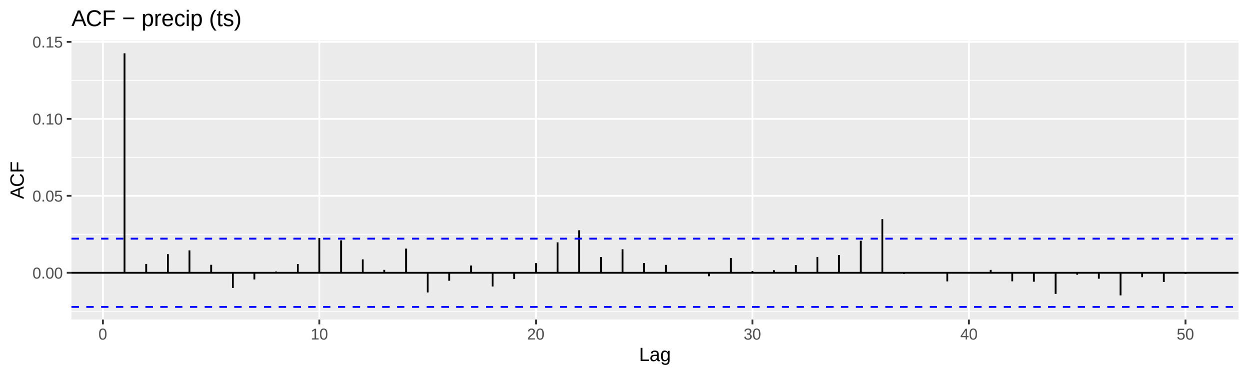

```r
print(autoplot(ts_precip) + labs(title='Precipitation (ts object)'))
```



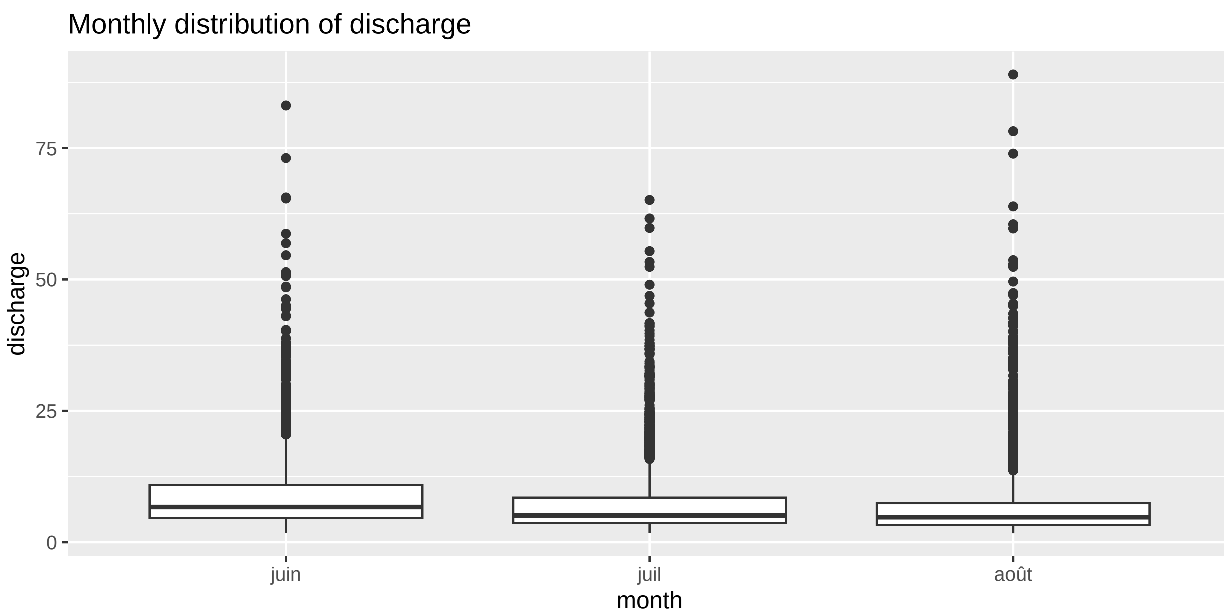

```r
# ACFs
print(ggAcf(ts_discharge, lag.max = 50) + ggtitle('ACF - discharge (ts)'))
```



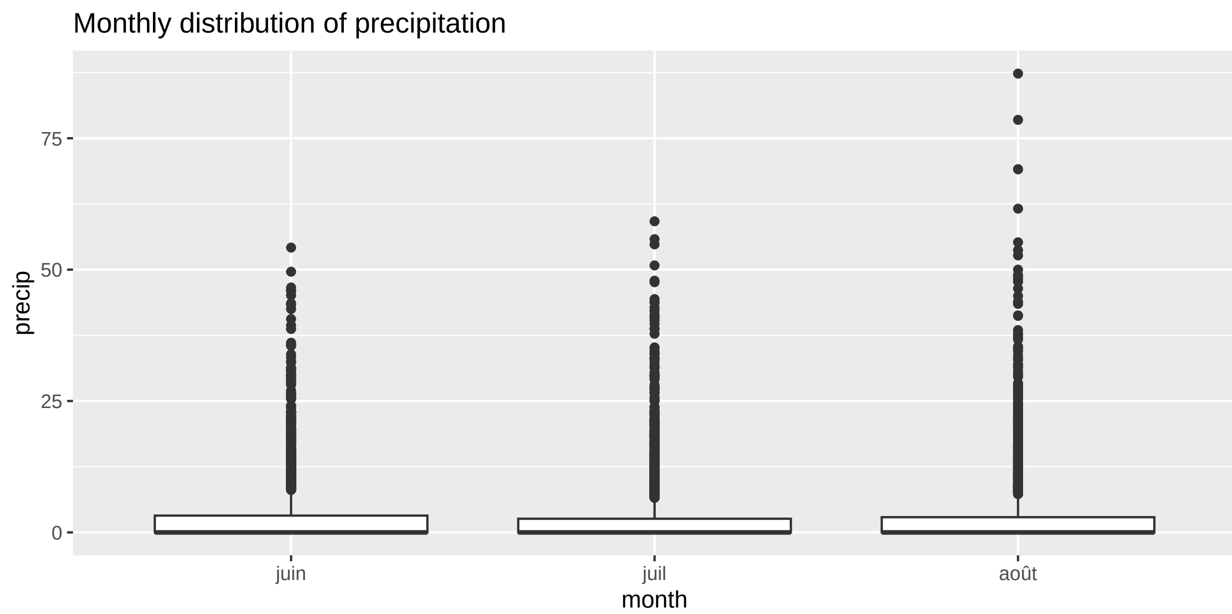

```r
print(ggAcf(ts_precip, lag.max = 50) + ggtitle('ACF - precip (ts)'))
```




```r
df <- df %>% mutate(month = month(date, label = TRUE))
print(ggplot(df, aes(x=month, y=discharge)) + geom_boxplot() + labs(title='Monthly distribution of disc
```




```r
print(ggplot(df, aes(x=month, y=precip)) + geom_boxplot() + labs(title='Monthly distribution of precipi
```



2 Summary statistics

Methodology

Compute simple descriptive statistics: mean, standard deviation and counts of missing values.

Results / Comments

The summary table provides an immediate check on data completeness and scale of the two series.

```
summary_stats <- df %>% summarize(
  n = n(),
  discharge_mean = mean(discharge, na.rm=TRUE),
  discharge_sd = sd(discharge, na.rm=TRUE),
  precip_mean = mean(precip, na.rm=TRUE),
  precip_sd = sd(precip, na.rm=TRUE),
  missing_discharge = sum(is.na(discharge)),
  missing_precip = sum(is.na(precip))
)
summary_stats
```

```
## # A tibble: 1 x 7
##       n discharge_mean discharge_sd precip_mean precip_sd missing_discharge
##   <int>          <dbl>        <dbl>       <dbl>     <dbl>             <int>
## 1  7819           7.93         7.36        3.07      6.77                 0
## # i 1 more variable: missing_precip <int>
```

3 Annual maxima and GEV for discharge

Methodology

Compute annual block maxima of daily discharge and fit a GEV via maximum likelihood. We then compute an approximate 100-year return level from the fitted parameters.

Results / Comments

The GEV parameter estimates and the 100-year return level are printed below. A histogram of annual maxima with the fitted GEV density is shown for visual fit assessment.

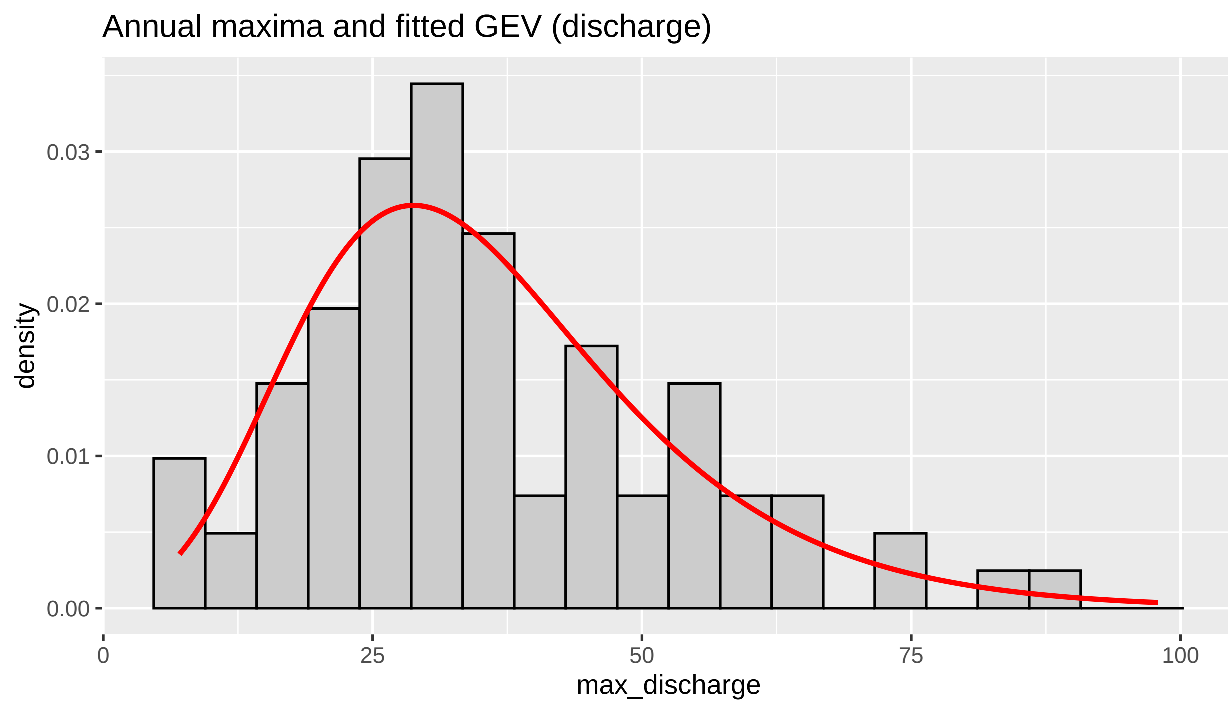
```
# annual maxima
library(stats)
df <- df %>% mutate(year = year(date))
annual_max <- df %>% group_by(year) %>% summarize(max_discharge = max(discharge, na.rm = TRUE)) %>% ung

gev_fit <- fgev(annual_max$max_discharge)
print(gev_fit)
```

```
##
## Call: fgev(x = annual_max$max_discharge)
## Deviance: 713.2291
##
## Estimates
##      loc     scale     shape
## 28.35273  13.90569  -0.03091
##
## Standard Errors
##     loc    scale    shape
## 1.70891  1.23774  0.08415
##
## Optimization Information
##   Convergence: successful
##   Function Evaluations: 29
##   Gradient Evaluations: 7
```

```
loc <- gev_fit$estimate['loc']; scale <- gev_fit$estimate['scale']; shape <- gev_fit$estimate['shape']
rl_100 <- qgev(1 - 1/100, loc = loc, scale = scale, shape = shape)
cat('Estimated 100-year return level (discharge):', rl_100, '\n')
```

```
## Estimated 100-year return level (discharge): 87.98176
```

```
xv <- seq(min(annual_max$max_discharge)*0.9, max(annual_max$max_discharge)*1.1, length.out=200)
gev_dens <- dgev(xv, loc=loc, scale=scale, shape=shape)
dens_df <- data.frame(x = xv, y = gev_dens)

p_gev <- ggplot(annual_max, aes(x = max_discharge)) +
  geom_histogram(aes(y = after_stat(density)), bins = 20, fill = 'grey80', color = 'black') +
  geom_line(data = dens_df, aes(x = x, y = y), color = 'red', linewidth = 1, inherit.aes = FALSE) +
  labs(title = 'Annual maxima and fitted GEV (discharge)')
print(p_gev)
```



4 Peaks-over-threshold (POT) and GPD for precipitation

Methodology

Select the 95% empirical quantile as threshold and fit a GPD to exceedances (ismev::gpd.fit). Use the empirical exceedance rate to compute approximate T-year return levels.

Results / Comments

The GPD fit and an example 10-year return level estimate are reported below.

```
threshold95 <- quantile(df$precip, 0.95, na.rm=TRUE)
th <- as.numeric(threshold95)
exceedances <- df$precip[df$precip > th]
excesses <- exceedances - th
cat('Threshold used (95%):', th, 'Number exceedances:', length(excesses), '\n')
```

```
## Threshold used (95%): 16.01 Number exceedances: 391
```

```
gpd_fit <- gpd.fit(df$precip, threshold = th, show = FALSE)
print(gpd_fit)
```

```
## $trans
## [1] FALSE
##
## $model
## $model[[1]]
```

```
## NULL
##
## $model[[2]]
## NULL
##
##
## $link
## [1] "c(identity, identity)"
##
## $threshold
## [1] 16.01
##
## $nexc
## [1] 391
##
## $data
##   [1] 24.1 18.5 38.7 39.7 40.6 23.0 21.1 18.3 29.6 55.2 21.0 26.5 19.6 35.0 22.7
##  [16] 27.0 31.6 26.4 17.3 40.4 16.6 19.5 22.1 16.1 24.4 28.6 41.1 27.7 19.7 21.1
##  [31] 30.6 18.4 16.9 16.8 22.9 26.5 28.1 22.9 43.6 24.1 33.9 20.9 29.1 25.1 50.8
##  [46] 20.5 19.0 43.9 21.0 20.6 36.1 26.8 20.2 23.3 29.0 23.0 16.7 20.9 28.6 43.3
##  [61] 26.6 20.2 17.8 19.5 18.7 27.3 20.6 22.3 36.7 30.0 34.5 22.6 33.9 31.4 32.4
##  [76] 22.8 25.5 26.6 21.3 20.3 16.5 29.6 30.1 18.2 27.7 16.2 35.4 18.2 16.4 49.0
##  [91] 21.8 17.7 24.9 25.4 41.5 18.6 25.5 30.3 20.1 41.2 38.7 19.5 17.0 30.5 16.6
## [106] 37.5 43.5 47.7 52.7 32.5 33.7 20.8 17.9 16.6 42.8 27.5 35.2 16.1 27.1 18.5
## [121] 20.3 33.2 17.2 17.2 19.9 26.6 38.5 18.0 30.5 16.7 27.9 16.6 22.2 16.2 24.3
## [136] 46.2 29.3 25.9 33.9 17.0 17.8 20.6 19.4 21.8 22.1 32.4 29.9 21.7 45.0 43.6
## [151] 21.0 19.0 18.1 26.1 54.8 21.4 33.0 34.4 46.4 21.6 28.1 28.4 30.5 21.7 43.7
## [166] 22.6 16.2 47.6 27.6 18.7 32.8 27.8 17.6 16.6 18.9 19.4 23.3 21.4 19.4 19.9
## [181] 20.8 28.1 21.6 37.9 29.6 42.2 18.0 27.8 53.7 17.0 18.5 21.6 27.0 17.7 21.3
## [196] 25.6 20.1 23.2 18.5 39.4 46.6 17.5 35.2 24.6 20.1 18.3 17.1 17.7 19.7 26.3
## [211] 17.3 21.0 20.6 17.4 59.2 17.9 33.1 16.8 35.2 31.6 61.6 20.7 22.1 19.4 33.3
## [226] 16.8 19.2 16.1 69.1 19.4 21.7 42.5 22.9 17.0 17.4 18.7 25.5 32.0 26.0 19.2
## [241] 37.1 69.1 19.5 20.5 21.3 21.8 20.5 31.4 17.4 34.7 16.8 22.7 18.9 18.5 18.0
## [256] 19.1 23.8 22.5 18.3 17.2 16.9 22.1 35.5 16.4 22.8 22.2 25.5 21.0 16.8 35.7
## [271] 21.7 22.2 18.1 19.7 27.3 23.1 35.6 29.9 20.8 23.0 30.3 21.1 18.6 18.3 30.2
## [286] 21.1 19.4 21.3 43.5 48.7 23.9 54.2 17.8 29.5 44.4 22.5 18.3 16.8 49.6 17.3
## [301] 30.8 25.0 19.9 20.1 27.9 18.4 33.1 19.5 16.1 20.4 31.9 47.9 16.4 21.4 21.9
## [316] 17.8 27.8 23.7 20.7 19.2 18.6 32.5 31.9 45.9 22.3 24.2 19.4 16.4 18.8 26.6
## [331] 22.4 20.0 41.3 16.7 31.2 40.9 23.9 31.3 29.8 48.2 25.8 24.6 18.6 16.3 18.6
## [346] 16.9 19.9 22.7 18.1 45.1 22.9 22.2 31.3 20.6 26.5 19.2 78.5 21.7 26.4 87.3
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## [391] 18.0
##
## $conv
## [1] 0
##
## $nllh
## [1] 1311.112
##
## $vals
##                                u
##   [1,] 10.45308 0.006331296 16.01
##   [2,] 10.45308 0.006331296 16.01
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##
## $mle
## [1] 10.453078987  0.006331296
##
## $rate
## [1] 0.05000639
##
## $cov
##              [,1]         [,2]
## [1,]  0.58402011 -0.028973011
## [2,] -0.02897301  0.002788572
##
## $se
## [1] 0.76421209 0.05280693
##
## $n
## [1] 7819
##
## $npy
## [1] 365
##
## $xdata
##     [1] 15.4  0.0  0.0  0.0  5.5  1.3  3.5  0.0  0.0  0.0  0.0  0.0  0.9  0.0
##    [15] 24.1  0.0  0.0  1.2  0.2  0.0  0.0  0.1  4.4  0.2  1.2  3.4  0.5  0.0
##    [29]  0.0  9.4  0.0  0.0  0.0  0.0 18.5  0.0  0.0  0.0  3.7  5.7  0.7  0.1
##    [43] 11.7  0.1  0.0  9.8 38.7  2.9  0.2  7.3  0.0 39.7  5.6  1.2  0.6  7.3
##    [57]  4.9  0.0  0.0  3.7  0.0  8.0  2.9 15.7  2.3 10.0  0.0  1.4  0.0  0.5
##    [71]  0.0  5.8  0.5  5.9  2.8  0.0  0.0  0.0  1.0  0.0  2.0  9.1  0.0  0.0
##    [85]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  6.4  1.5  0.0  0.0  0.0  4.0  3.7
##    [99]  0.3  0.0  0.0  0.0  0.3  0.0  0.0  0.0  0.0  7.3  2.4  0.0  2.5  0.0
##   [113]  0.0  0.1 40.6  7.5  0.0  0.1  8.2  0.0  0.0  5.5  0.0  9.1 14.4  0.0
##   [127] 23.0 21.1  1.7  0.6  0.0  0.0  0.0  4.7  9.4  8.6  1.2  0.0  0.0 14.4
##   [141]  9.9  1.1  0.0  0.5  0.0  0.0  0.0 18.3  2.2  0.0  0.0  0.0  4.1  3.0
##   [155]  2.3  0.0  0.3 15.6  7.1 29.6  2.8  0.6  1.1  0.0  0.0  1.1 55.2  0.5
##   [169]  3.9  0.5  6.6  5.1  8.5 14.9 10.7 10.5 11.3  0.0  0.0  0.0  5.1  4.4
##   [183] 14.3  6.3 21.0  0.2  0.2 26.5  1.1  0.1  0.0  0.0  0.0  0.0  4.8 19.6
##   [197]  0.0  0.0  0.0  0.0  0.0 14.5  1.8  3.8  1.1  1.7  6.0  1.7  0.0  0.0
##   [211]  0.0  0.0  0.0 35.0  4.8  0.0  0.0  8.0 22.7  2.0  1.7  5.6  0.0  1.7
##   [225]  2.5  6.3  0.1 11.7  1.6  1.6  0.0  1.0 27.0  0.0  0.0  5.3  0.0  1.9
##   [239]  0.9  0.4  0.0  0.0  0.0  0.2  6.6  1.3  4.1  8.0  4.3  0.0  0.0  0.0
##   [253]  0.0  0.0  0.0  0.0  0.0  5.2  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
##   [267]  3.5  0.0  0.0  0.0 31.6  0.0  0.0  9.3  0.0  3.4  0.0  0.0  0.0  0.0
##   [281]  0.0  0.0  0.0  0.0  1.4  1.8  7.6  2.7  0.2  0.2  0.7 26.4  7.4 17.3
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##  [295] 11.8 10.6  3.6  1.5  4.8  6.6  7.2  0.0  4.3  1.7  0.1  0.0  0.0  0.0
##  [309]  0.0  0.0  0.0  6.5  0.0  8.0  0.0  1.2  6.6  0.0  6.5 40.4  2.7  0.0
##  [323]  0.0  0.0  0.2  0.0  9.1  0.2  0.0  0.0  0.0  0.0  0.9 16.6  0.8  0.0
##  [337]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  8.9
##  [351]  0.8  3.4  4.6  0.0  0.0  8.1  0.0  0.9  5.0  0.0  0.0  0.0  0.0  0.0
##  [365]  0.0  0.0  0.0  9.9  1.7  5.2  0.0  0.0  0.0  0.3  0.0  0.0  0.0  0.3
##  [379]  0.1  0.0  0.0  0.4  0.0  0.0  0.0 13.0 19.5  0.2  0.0  0.0  8.5 22.1
##  [393]  0.0  0.0 13.3  4.7  3.3  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
##  [407]  1.6  1.6  3.0  8.8 11.5  1.2  0.0  0.0  0.0  0.0  8.9  0.9 12.2  0.7
##  [421]  7.2  7.2  0.2  0.0  0.0  0.0  0.0  4.2  0.3 16.1 24.4  2.5  0.0  0.2
##  [435] 11.7  0.0  1.7  0.0  0.6  0.0  4.3 13.5  0.1  0.0  0.0  0.0  0.0  0.0
##  [449]  0.0  0.2  3.4  1.4  5.0  0.1  0.0  0.0 10.9  8.4 10.7  0.0  2.4  6.3
##  [463] 28.6  3.6  0.0  0.0  0.0  4.3  0.0  5.5  0.0  0.0  0.0 13.4  0.0  0.4
##  [477]  2.2  0.0  0.0  0.0  0.0  1.1  0.0  0.0  0.0  0.0  0.0  0.0  0.0 41.1
##  [491]  0.0  1.8  0.0  0.0  0.0  0.0  0.0 27.7  0.2  0.0  0.0  0.0  0.0  0.0
##  [505]  0.0  0.0  0.8  0.0  7.6  0.0  0.0  0.0  0.0  4.3  7.6  0.0  0.0  0.0
##  [519]  0.0  0.0  0.6 11.2  0.7 19.7  0.0  0.0  0.0  1.1  1.9  4.8  0.0 15.6
##  [533] 21.1  2.3  0.0  0.0  0.0  2.8  2.6  0.0  0.0  0.0  0.0  8.4  6.0 10.7
##  [547]  4.0 30.6  4.2  0.0  0.0  0.0  1.5 18.4 13.2  0.0  2.4  0.4  1.7  0.0
##  [561]  1.7  0.9  0.0  5.0  1.6  0.0  0.0  0.0  0.0  0.0  0.0  3.9  6.0  0.0
##  [575]  0.0  2.0  5.1  9.3  0.0  5.1  0.0  3.4  2.4  7.2  0.0  0.0 12.9  5.1
##  [589] 16.9 14.4 11.1  5.3  4.9  9.8  1.0  2.8  0.0  0.0  0.8  0.0 11.9  1.9
##  [603]  0.2  0.0 13.1  3.0  0.0 16.8  9.6  3.7  0.3  0.8  8.8  0.4  1.8  1.2
##  [617]  0.0  0.0  1.8  0.0  0.0 22.9  8.0  3.6  0.6  0.0  0.0  9.6  0.0  0.0
##  [631]  0.7  0.1  0.0  1.7  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0 26.5
##  [645]  0.0  0.0  0.0  0.0  0.0  6.6  0.0 28.1  0.0  9.2  0.0  0.0  0.0  2.6
##  [659]  0.2  0.0  0.0  4.4  3.8  0.3  0.0 10.1  3.9  0.2  0.0 14.8  8.1  8.0
##  [673]  0.0  0.0  0.0  0.0  0.4  8.3  1.1  3.7  0.0  0.0  0.6  0.9  3.5  0.4
##  [687]  0.0  3.5  0.1  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
##  [701]  0.0  0.0  0.0  9.2  5.7  0.0  0.0  0.0  0.0  0.0  0.0  0.0 14.7  0.0
##  [715]  0.0 15.9  8.6  6.0  0.1  0.6  1.2  0.1  0.0  2.8  1.7  8.4  0.0  0.0
##  [729]  0.0  0.0  0.0  0.0 22.9  2.3  0.0  7.8  5.6  0.0  0.0  0.6  0.0  0.0
##  [743]  0.0 12.7  5.2  5.4 43.6 24.1  0.2  0.6  0.0  0.0  0.7  0.0  0.0  0.0
##  [757]  6.8  4.5  0.0  0.2  0.1  0.0  0.0  0.0  4.9 33.9 20.9  1.7 29.1 16.0
##  [771]  0.0  0.0 25.1  0.0  2.1  0.8  9.7  0.2  0.0 50.8  2.4  0.0  0.0  0.0
##  [785]  0.0  0.0  0.0 20.5 19.0  0.0  2.4  0.0  0.1  0.0  0.0  0.0  0.0  0.0
##  [799]  0.0  0.0  0.0 43.9  0.0  0.4  0.9  0.0  3.1  4.2 10.3  2.8  0.0  0.0
##  [813]  0.0  0.0  0.2 21.0  3.5  0.1  0.0  0.0  0.0  0.0  0.5  6.6  8.4  1.7
##  [827]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  3.3 20.6  2.8  2.1
##  [841]  0.2  0.0  2.2  4.6  0.0  3.7  0.0  0.0  2.2  7.5  6.5 15.6  6.4  0.0
##  [855]  0.0  0.9 36.1  0.0  0.9  0.0  0.0  1.0  1.4  0.0  0.0  0.3  0.0  0.0
##  [869]  0.0  0.8 14.8 12.1 12.2  0.0  0.0  1.2  5.7  6.0  4.8  5.2  8.3 12.4
##  [883]  1.6  0.8  0.0  0.0  0.0  0.4  0.0  0.0  6.1  7.3 26.8  0.4  4.9 10.5
##  [897]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  1.7  4.2  1.5  0.5  0.6
##  [911]  0.6  0.0  0.4  0.1  0.0  0.4  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
##  [925]  0.0  0.0  0.0  0.0  1.0  7.1 10.2  0.0 10.3  1.4  5.6  0.3  0.0  1.5
##  [939]  0.2  0.1  4.3  0.7 10.1 16.0  0.3  0.0  0.0  0.0  0.0  0.0  0.3  0.0
##  [953]  0.8  0.0  1.9 20.2  1.7  0.0  0.1  7.0 13.1  0.1  1.7  9.1 12.3 10.5
##  [967]  0.0  0.0  6.8  0.5 11.2  1.6  0.0  0.2  2.2  0.0  0.0  0.0  0.0  0.0
##  [981]  0.0  0.0  0.0  0.0  3.4  2.9  0.0  0.0  0.1 23.3  0.0  0.0  0.0  0.0
##  [995]  0.0  0.0  0.0  0.0  2.2  0.8 14.1  1.7  1.2  0.0  0.0  0.0  0.3  2.6
## [1009]  0.0  0.0  0.0  0.0  0.9  0.0  0.1 14.8  1.9  5.5  0.0 13.2  8.6  2.1
## [1023] 29.0  0.3  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  6.1
## [1037] 23.0  3.8  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
```

```
## [1051]  2.4  6.0  0.0 15.4  0.0  5.0  1.1  0.0  0.0  0.0  0.8  0.0  0.0  0.0
## [1065]  0.0  0.0  0.0  0.0  0.3  3.8  3.8  4.3  0.0  0.0  5.9  2.5  9.7  0.2
## [1079]  2.5 12.7  6.1  0.0  0.0  1.4  0.0  0.0  1.5 16.7  0.1  7.2  0.1  1.8
## [1093]  1.2  0.0  0.2  0.2  0.0 13.5  0.0  0.0  3.6  2.2  0.0  0.0  0.0  0.0
## [1107]  0.0  0.0  0.0  4.3 20.9  4.6 28.6 43.3 12.5  0.3  4.9  2.6  3.5  0.0
## [1121]  0.0  0.0  0.0  0.0  0.0  0.0  1.0  0.5  0.0  0.0  0.0  0.0  0.0  2.5
## [1135] 12.1  0.2  0.0  1.8  0.0  0.1  0.0  0.6 10.0  0.1  0.0  0.0  8.3  4.1
## [1149]  0.0  2.8  0.0  5.7  7.5  1.3  0.6  0.0  0.0  1.1  0.2  0.0  0.0  0.0
## [1163]  0.0  0.0  6.9  7.7 15.8  1.9  1.0  0.0  0.0  0.0  0.1  0.0  0.0  0.0
## [1177]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  6.8  0.0  0.0  0.4  0.0  0.0  0.0
## [1191]  0.0  0.0 12.4  0.0 26.6  7.3  4.3  4.6  6.1  0.0  3.4  0.0  9.4  0.9
## [1205]  0.0  0.0  0.0  0.0  9.6  4.0 11.1  8.2  0.0  0.0  0.0  0.0  0.0  0.0
## [1219]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.9  7.3 20.2
## [1233] 13.3  3.0  0.4  0.1  0.0  1.0  0.0  0.0  0.9  0.0  0.0  4.0  7.0  3.6
## [1247]  6.0 10.9  0.0  0.0  0.0  0.2  0.0  0.0  0.0  0.0  0.0  0.0  6.9  0.0
## [1261]  0.1  0.0  0.1  0.0  0.0  0.0  7.1  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [1275]  0.0  0.0  0.0 17.8  0.0  0.0  0.0  0.9  0.2  0.0  0.0  0.8  0.0 19.5
## [1289]  0.0  0.0  0.0 10.0  1.3  0.3  0.0  1.0 18.7  0.0  0.0  0.0  0.0  0.0
## [1303]  6.6  0.4  2.0  1.5  0.0  0.0  0.0  0.0  0.0  0.0  1.7  8.9  0.8  2.1
## [1317]  0.0  0.0  0.0 27.3  4.1  0.0  0.0  3.1  6.0  2.3 12.1  0.8  0.0  0.0
## [1331]  1.3  0.0  0.0  0.0  0.0  0.0  7.2 20.6  6.0  0.1  0.0  0.0  2.6  0.3
## [1345]  0.0  1.1  0.0  0.0  0.0  0.0  0.0 11.5  0.0  0.2  0.0  0.0  0.3  0.0
## [1359]  0.0  0.0  0.0  0.0  1.6 11.3  0.4  0.0  0.0  0.0  0.0  0.0  0.0  1.0
## [1373]  2.3  1.9  0.2  0.9 22.3  3.0 36.7  1.1  0.0  0.0  0.0  2.5  0.0  0.0
## [1387]  0.0  0.8  0.0  0.0  6.9  0.1  0.0  0.0  5.1  0.0  0.0  0.0  0.0 30.0
## [1401]  0.0  0.0  0.0  0.0 13.9  0.0  4.1  0.0  0.0  0.0  6.0  0.3  0.0  0.0
## [1415]  0.0  0.0  0.0  1.8  2.8  0.0  0.0  0.0  0.0  5.9  0.0  0.0  0.0  0.0
## [1429]  0.0  0.0  0.0  0.0  0.0  0.0  7.0  1.1  5.6  0.0  0.0  0.0  0.0  0.0
## [1443]  0.0  0.0  0.0  0.0 34.5  8.8  6.3  8.9  0.0  0.0  1.1  0.0  0.8  0.0
## [1457]  0.0 22.6 14.5  0.3  1.8 14.3  5.9  0.0  0.0  0.0  0.0  0.0  3.1 14.4
## [1471]  0.0 33.9  2.4  1.4  0.0  0.0  0.0  0.5  0.0  7.2  6.2  1.0 31.4 32.4
## [1485]  0.0  3.6 22.8  1.2  0.3  0.0  0.0 25.5 15.8  0.9  0.6  0.7  6.3  0.0
## [1499]  0.0  0.2  0.6  0.0  0.0  0.0  0.0  2.4  2.0  2.6  1.0  0.0  0.0  0.0
## [1513]  0.0  1.4  0.0  0.3  0.0  5.0 10.6  0.0  2.9  4.9  0.0  0.0  0.0  0.0
## [1527]  0.0  0.0  8.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  6.3  0.0  0.0  0.0
## [1541]  0.0  4.0  0.2  2.3  4.0  0.0  0.0 11.4 26.6  6.7  2.3  3.1 11.1  0.0
## [1555]  0.0  0.0 10.0  1.2  0.0 21.3 20.3  9.8  0.4  0.0  0.0  0.0 16.5  0.0
## [1569] 10.9  1.8  0.6  0.0  0.0  0.0  9.4  6.0 10.0  3.7  0.0  0.0  0.0  5.4
## [1583]  0.0  0.0  1.1  0.0  0.0  0.0  0.0  0.0  0.0  0.0  4.5  3.1  0.0  0.0
## [1597]  1.1  0.0  0.0  9.3 10.8  4.3  0.1  1.0  0.0  0.0  0.0  0.0  3.8 29.6
## [1611]  1.6  1.8  0.2  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [1625]  0.0  0.0  0.0  1.9  4.6  0.0  0.0  0.0 11.0  0.2  0.0  0.0  0.0  0.0
## [1639]  0.3  0.0  0.0  0.0  1.4  0.0  2.7 12.2  0.0  0.0  0.0  0.0  0.0  0.0
## [1653]  0.0  0.0  0.0  3.5  0.0  2.6  6.9  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [1667]  0.0  0.0  0.0  4.3  1.5  0.6  5.4 12.4  1.7  0.0  2.7  4.6  0.0  1.5
## [1681]  0.0 13.8  3.2  5.5  5.2  6.1  0.0  0.0  7.9 10.7 11.6  0.0  0.5  3.2
## [1695]  2.8  0.0  4.1  5.0 30.1 10.4  4.5  7.3  6.2  0.0  1.3  0.0  0.0  2.1
## [1709] 15.3  0.0  0.0  0.0 18.2  0.4  3.6  0.0  0.0 27.7  8.3  5.5  0.0  2.7
## [1723]  1.2 16.2  2.1  4.7 35.4  8.4 15.7  1.1  0.0  0.0  0.6  8.1  7.7  0.0
## [1737]  1.3  5.5  0.0  1.4  0.0  0.0  0.0  0.2  0.0  0.0  0.0  1.7  6.4  4.6
## [1751]  2.5  0.3  0.0  2.5  1.4 13.0  1.3  0.0  0.0  0.0  0.0  0.8  0.0  0.0
## [1765]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [1779]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  2.3
## [1793] 18.2  0.6  8.9  0.2  0.0  0.0  0.0  0.0  5.6  0.0  0.0  0.0  0.0  0.0
```

```
## [1807]  0.0  0.0  0.0  4.8  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  1.5  0.2
## [1821]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.3 10.2  1.3  6.7
## [1835]  0.2  5.6 10.1  0.0  0.0  0.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [1849]  0.0  0.0 13.0  0.0  3.7  5.9  7.4 10.0  0.7  0.0  0.0 12.9  0.0  0.0
## [1863]  0.0  0.5  0.0  0.0  0.0  0.0  0.0 12.2  0.0  0.0  0.0  2.8  0.0  0.0
## [1877]  0.0  1.8  1.2  0.4  0.1  0.0 16.4  0.0  0.0  0.0  0.0  0.0  0.0  0.9
## [1891]  0.1  5.7  0.0  0.0  1.4  1.2  5.5  0.0  0.0  3.4 49.0 21.8  2.2  1.3
## [1905]  0.0  0.0 17.7  0.0  0.0  7.2  0.0  0.0  0.0  0.0  0.0  0.6 15.4  0.0
## [1919]  0.0  0.0  0.0  0.0  0.0  9.5 10.8  2.8  6.4  6.1  0.0  0.0 24.9  1.3
## [1933] 13.6  0.0  0.1  1.1  1.6  0.6 25.4  6.4  0.0  0.0  2.7  0.0  0.0  0.0
## [1947]  1.1  9.4 10.0  5.4  0.0  0.4 14.5  7.6  1.4  1.5  2.3  2.8  4.9  0.0
## [1961]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  2.4  3.1  0.0  3.7  3.4 41.5
## [1975] 13.5  9.2  5.0  0.0  0.0  0.0  0.0  0.0  0.0  4.2  0.0  0.0  0.0  0.0
## [1989]  0.0  0.0  0.0  2.8  0.2  0.0 13.7  5.7  0.0  1.5 18.6  8.8  0.3  3.2
## [2003]  0.0  0.4 15.7  0.0  0.0  3.1  0.0  0.0  0.2 25.5  1.8  0.0  0.0  0.0
## [2017]  0.0  7.5  1.3  0.0  0.0  1.4  9.1  4.6  5.0  0.0  0.0  0.0  8.8  4.4
## [2031]  0.0  0.0  0.0  0.0 11.4  0.5  0.0 16.0  4.4  1.0  3.5  0.0  0.0  0.0
## [2045]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  5.3  0.1  0.0  0.0
## [2059]  0.0  0.6  2.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [2073]  0.0  0.0  1.4  0.0  0.0  0.0  0.0  0.0 12.9  0.0  0.0  0.0  0.0  1.0
## [2087]  0.4  0.0  0.0 30.3  0.2  0.0 12.2  0.0  0.0  0.0  0.0  0.0 20.1  5.4
## [2101]  0.1  3.1  0.7  8.6  4.3  0.0  1.6  0.5  0.0  0.0  0.0  0.0  0.1 41.2
## [2115]  2.5  1.2  4.6  1.9  0.0  0.0  0.0  0.7  9.5 38.7 19.5  0.1  0.0  0.0
## [2129]  0.0  0.9  6.3 12.9  4.0  0.0  0.0  5.8  8.8  6.4  6.7  8.1  2.4  0.4
## [2143]  1.0  3.2  0.3  0.4  0.0  6.2  0.4 17.0  1.7  0.0  0.0  0.3 15.0  0.0
## [2157]  6.4  4.4  0.0  0.0  0.0  0.1 10.3  0.0  0.0  0.0  0.6 16.0  0.0  0.0
## [2171]  0.0  0.0  0.0  0.3  0.7  3.1  0.1 30.5  0.1  0.0  0.0  0.1  0.0  0.0
## [2185]  0.0  0.0  0.0  0.0  0.0  0.0 16.6  1.8  0.0  0.0  0.0  4.0  6.6  0.7
## [2199]  0.0  2.7  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.2  0.0  4.5  0.8  1.0
## [2213]  1.1  0.0  0.0 11.5  2.0  0.5  0.4  2.6  0.0  0.0  0.6  0.2  0.0  0.0
## [2227]  0.0  0.6  0.0  0.0  0.0  0.0  0.0  3.8  1.0  0.0  7.0  4.3  2.2  0.0
## [2241]  6.4  0.0  4.0 15.4  0.0  0.0  0.6  0.0  0.1  0.0  4.3  1.2  0.0  0.1
## [2255]  1.8  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.7  4.8  0.4
## [2269]  0.0  0.0  0.0  4.6  0.0  5.7  0.0  1.4 37.5  2.1  0.1  1.9  0.7 43.5
## [2283]  0.6  1.9  0.0  2.4  0.0 47.7 52.7  4.9  2.3  1.7  9.4  0.9  0.0  0.4
## [2297]  0.0  0.0  0.0  5.2  0.0  8.8 11.1  0.1  0.1 32.5  1.0  8.3  0.0  0.5
## [2311]  8.5  0.2  0.0  0.0  0.3  1.7  1.1  5.8  1.9  0.7  1.9  0.0  0.0  0.3
## [2325]  0.7  0.0  0.1  0.1  0.4  0.0  7.5  6.1  0.2  0.0  0.0  1.8  0.0  0.0
## [2339]  0.0  0.4  8.6  1.4 11.6  0.2  0.0  0.0  2.4  0.4  4.5  2.3  8.7  0.0
## [2353]  0.0  5.3  1.5  8.9  7.8  0.6  0.0  0.0  0.0  0.2  0.7  0.0  0.0  0.0
## [2367]  5.0  0.0  0.0  0.0 15.2  2.4  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [2381]  0.0  0.0  0.0  0.0  0.7 14.0 33.7  7.1  2.9 20.8 12.0  0.0  0.0  0.0
## [2395]  0.1  0.0  7.7 14.1  4.6  0.2  0.1  0.0  1.6  2.3  4.2  0.7  0.4 11.3
## [2409]  0.0  0.0  0.3  0.0  0.1  0.0  0.4  0.0  0.0  0.0  0.0  0.0  0.0 17.9
## [2423] 16.6  0.1  0.0  0.0  0.0  0.0  0.2  8.0 10.2  3.5  0.0 42.8 11.5  0.6
## [2437]  4.9  0.0  9.0 27.5  3.6  2.2  0.0  0.0  0.0  0.0  0.0  1.0  7.1 10.2
## [2451]  0.0  0.0  5.6  4.8  2.6  0.3  1.8 11.1 12.4  0.0  0.0 12.9  3.2  0.0
## [2465]  0.1  0.2  0.0  0.0 14.6  7.3  0.0 35.2  4.8  3.5  3.7  4.9 16.1  2.8
## [2479] 27.1  0.2  4.7  0.0  3.9  1.4  0.0  1.4  2.7  5.3  0.2  5.3  6.5  2.8
## [2493] 12.0 18.5  0.5  0.0  5.5  0.3 14.5  0.6  0.0  1.4  2.0  7.9  3.2 12.5
## [2507] 10.1  0.1  0.1  0.0  0.0  0.0  0.0  0.1  0.0  0.0  0.0  0.0  0.0  0.0
## [2521]  0.1  0.0  3.5  0.5  1.0  0.6  0.1  2.1  8.5 20.3  7.9  3.0  6.6 33.2
## [2535]  4.4  0.0  5.2  0.3  0.0  6.5  1.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [2549]  1.6  5.1  0.0  0.0  1.5  0.0 14.5  8.8 17.2  0.2 11.4  0.5  0.0  1.8
```

```
## [2563]  1.5  0.0  0.4  0.0  8.3  0.2  0.7  0.0  6.0  0.1  0.0  0.0  0.0  0.0
## [2577]  3.0  3.0  0.0  0.0  5.7  7.0  0.0  0.0 17.2  0.1  0.0  0.0  0.0  0.0
## [2591]  0.0  0.0  0.0  4.0 15.6  3.0  3.3  0.0 15.5  1.3  9.7  1.0  0.0  0.0
## [2605]  0.6  4.3  7.2  3.1 11.9  1.0  0.0  9.5  0.0  0.0  0.0  0.0  0.0  1.9
## [2619]  0.0  0.2  5.5  0.0  0.0  0.0  0.0  6.4  2.8  1.8  6.8  0.0  1.9  0.2
## [2633]  0.0  0.8  0.0  0.0  0.0  3.1  0.0  0.0  0.0 12.6  5.5  0.0  0.0  0.0
## [2647]  6.8  0.0  1.9  0.0  0.0  0.6  9.1  0.0 19.9  1.8  9.8 10.4  1.8  3.2
## [2661]  5.1  1.1  0.0  0.0  0.0  0.0  5.0  0.0  0.0  0.0  0.0  1.6  0.3 13.2
## [2675]  0.0  1.0  0.0  0.0  0.5  0.4  0.0  0.0  0.0  0.1  5.7  0.5  1.0  0.3
## [2689]  9.9  2.5  0.1  7.5 11.7  0.0  9.9  9.7  6.6  1.8  0.0  0.0  0.0  0.0
## [2703]  0.0  0.0  0.0  0.0  0.0  2.9 13.6  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [2717]  0.0  0.0  0.0  2.4  6.4  0.0  0.0  0.0 26.6  7.6  0.0  0.6  0.0  0.8
## [2731]  0.0  0.0  0.0  0.0  0.0  5.5  0.0 14.1  0.0  1.4  0.0 10.7  0.0  0.0
## [2745]  0.0  0.0  0.0  0.6  3.0 38.5  4.9  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [2759]  0.0  1.2  1.8  0.6  9.0  0.0  0.4  0.0  4.1 11.1  4.2  0.0  0.0  0.9
## [2773]  0.0  0.0  0.0  0.0  0.0  2.4  0.0  0.0  0.0  1.2  4.5 18.0  3.3  1.7
## [2787]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  1.4 30.5  9.1  1.2  3.3 16.0
## [2801]  0.2  0.0  4.2 11.4  0.0  0.0  2.1 16.7  0.4  0.0  0.1  0.1  0.0  0.0
## [2815]  0.2  1.2  0.0  0.0  0.7 15.1  5.4  3.2  0.0 27.9  9.5  0.7 16.6  3.0
## [2829]  3.2  0.0 22.2 13.6  0.2  2.3  0.3  0.0 16.2 24.3  0.0  0.0  0.0  0.0
## [2843]  0.0  0.0  0.0  0.0  5.8  9.3  0.0  0.5  0.4 11.6  0.2  0.0  0.0  0.0
## [2857]  7.1  0.2  7.1  7.4  0.1  1.6  2.1  1.4  0.0  0.0  0.0  0.0  0.0  0.0
## [2871]  0.0  2.2 46.2  0.0  0.0  6.9 29.3 25.9  0.0  0.0  0.0  0.0  0.0  0.0
## [2885]  0.3  0.0  0.0  0.0  0.0  0.0  0.0  9.6 14.9  6.7 33.9  5.3  3.0  2.1
## [2899]  4.8 17.0  0.0  0.0  0.0  0.0  1.2  0.0  0.0  1.6 11.9  0.7  0.0  0.0
## [2913] 12.7  1.0  0.0  0.0  0.0  0.0 17.8 20.6  5.1 19.4  4.9  8.6  0.0  0.0
## [2927]  2.8  5.6  0.5  0.0  0.1  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [2941]  0.0  0.0  0.0 21.8  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [2955]  0.0  0.0  1.4  1.8  0.0  6.3  0.0  1.6  0.0  0.0  0.0  0.0  0.0  0.0
## [2969]  0.0  0.0  0.0  0.3  0.0  0.0  0.0  2.1  1.6  0.0  0.1  0.0  0.0  0.0
## [2983]  3.1  0.5  0.0  0.0  7.6  7.8  5.7  0.2  0.0  0.0  0.0  0.0  0.0  0.0
## [2997]  0.0  0.0  0.0  0.0  5.8  0.6  0.0  0.0  0.0  8.8  0.0  9.5  0.6 12.5
## [3011]  1.2  0.6  0.0  0.0  0.0  0.0  0.0  0.0  3.0  0.0  0.1  0.0  0.0  8.3
## [3025]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  2.0  8.9
## [3039]  5.0  0.0  6.8 22.1 32.4  2.4  3.3  1.5  0.2  4.9 12.8  1.6  0.0  0.0
## [3053]  3.2  0.0  0.0  0.0  7.3 29.9  5.8  4.0  0.0  2.0  2.6  0.0 12.8  3.9
## [3067]  0.0  0.1  0.0  4.1  0.0  9.1  0.0  0.0  2.8  0.3  0.0  7.7  0.0  0.0
## [3081]  0.0  1.1  0.0  0.0  0.0  0.0 21.7  0.1  0.0  3.2  0.0  0.0  0.0  0.0
## [3095]  0.0  0.0  0.0  0.0 45.0  0.0  0.0 43.6  3.9  0.8  0.6  0.0  1.4  6.7
## [3109] 12.8 21.0  3.0  0.0 11.2 19.0  0.5 10.4  6.6  2.8  0.2  0.0  0.0  2.1
## [3123] 12.1  1.6  0.1  0.0  0.6 13.4  0.4  0.0  0.0 18.1  0.0  3.4  0.4  0.0
## [3137]  0.0  0.0  0.0 11.5  3.9  0.1  0.0  0.0 16.0  0.0  3.8  2.5  0.0  0.0
## [3151]  0.0  0.0  0.5  0.4  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [3165]  0.0  4.0  1.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.1  0.0  0.0  0.0
## [3179] 10.4  0.0  0.0  0.0  0.0  0.3  2.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [3193]  0.0  0.0  8.6  0.0 11.9  0.2  6.9  0.0  0.0  0.0  0.3  0.0  0.1 13.0
## [3207]  0.6  0.0  2.6  3.1  0.0  0.0  0.0  0.0  0.0  0.1 26.1  0.0  0.0  0.0
## [3221] 11.0  3.1  8.1  2.4  0.0  2.2  4.0  3.7  0.3  0.0  0.0  0.0  0.1 10.2
## [3235] 10.8  0.2  0.0  1.2 15.8  0.7  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [3249]  0.0 11.4  0.0  3.2  0.2  0.1  0.0 54.8  8.2  5.6  0.1  0.0  0.0  0.0
## [3263]  0.0 15.2  2.1  0.0  0.0  0.0 21.4  3.3  1.2  4.4 33.0  4.3  0.7  0.7
## [3277]  0.0  0.0 34.4  0.0  2.2  3.0  0.0  0.0  0.0  0.0  0.3  0.0  0.0  2.1
## [3291]  0.0  0.0  0.0  6.0  0.0  1.4  0.0  0.0  0.0  0.0 15.2 46.4  0.0  3.6
## [3305]  1.7  0.9  6.0  0.0  0.0  0.0  7.5  0.0  0.0  0.0  0.0  3.2  0.0  0.0
```

```
## [3319]  2.8  3.4  0.0  6.9  0.0  0.0  0.4  0.0  0.0  0.0  3.2  4.0  2.9  0.0
## [3333]  3.8  0.1  0.8  0.0  1.7  0.0  0.0  0.1  0.0  0.0  0.0  0.6  0.0  8.1
## [3347] 11.9  0.4  0.0  0.0  0.3  9.3  0.0  0.6  0.2  0.0 11.2 10.4 10.8  0.1
## [3361]  0.0  0.4  0.0  1.8  0.5  0.4  0.0  0.0  0.0  0.0  0.6  0.0  0.8 21.6
## [3375] 28.1  8.5  0.2  0.0  4.7  4.1  0.0  0.0  0.0  0.0  0.0  0.0  9.7  0.1
## [3389]  0.7  0.0  2.5  6.5 28.4  5.6  0.0  0.0  1.9  0.0  0.0  0.0 12.7  1.7
## [3403]  1.3  0.0  0.0  0.0  0.0  0.0  0.0 30.5  0.6  0.5  0.0  0.1  0.0  0.0
## [3417]  0.0  0.7  0.0  0.0  1.4  0.0  0.0  0.0  0.0  0.0  0.0  0.0 21.7  9.9
## [3431]  0.0  0.0  0.0  0.0  1.3  0.2  0.0  0.0 43.7 11.5  6.3  0.0  0.0  0.0
## [3445]  0.0  1.5  8.9  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  1.5  7.4
## [3459]  0.0  0.0  0.0  0.0  0.0  6.9  0.0 22.6  0.4  9.6  0.0  0.0  0.0  0.0
## [3473] 14.5 16.2  0.0  8.7  0.0  6.9  0.0  8.6  0.7  0.0  0.0  0.0  0.0  0.0
## [3487] 13.3  0.9  0.0  0.0  0.0  0.0  0.0  1.0  0.0  0.0  3.9  3.0  0.0  0.0
## [3501]  0.0  0.0  1.4  0.0  0.0  0.0  0.0  1.9  0.1 11.1  0.9  4.0  0.0  1.1
## [3515]  2.1  0.8  0.0  9.8  0.0  0.0  1.0  0.0  0.0  0.0  0.0  0.0 47.6  0.0
## [3529]  0.0 27.6 15.3  0.0  0.0  0.0 18.7  2.8  0.0  2.2  9.3  2.2  2.0 15.2
## [3543]  0.5  0.0  0.0  0.0  0.0  0.5  3.0  0.0  0.0  0.0  0.0  0.0  0.0  2.4
## [3557] 32.8 27.8  5.3  0.0 17.6 11.0  2.4  1.4  0.1  1.4  2.2  5.9 10.0 16.6
## [3571]  0.0  0.0 18.9 12.9  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  9.5 12.2
## [3585] 14.3 12.4  0.1  0.0  0.0 13.0  0.0  8.1  1.1  0.5  0.0  0.0  0.0  0.0
## [3599]  0.7 13.2  0.9  0.0  9.7  0.0 14.6  5.0  0.2  5.4  0.0 13.7 15.5 12.5
## [3613]  0.0  4.1  0.0  0.0  0.0 15.6  0.0  0.0  0.0  0.0 10.1  2.7  3.6  1.1
## [3627]  0.0 19.4  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [3641] 23.3 13.1  6.2 12.8  0.0  3.4  0.0  0.0  0.0  5.4  0.0  0.0  0.0  0.5
## [3655]  0.0  0.0  0.0  0.0  0.0 21.4  1.9  8.8  3.2  6.3  1.9  0.0  0.0 19.4
## [3669]  0.0  0.9  3.9  3.1  0.9 12.0  1.5  2.1  0.0  0.0  0.0  0.0  0.0  0.0
## [3683] 19.9  6.9  0.0  7.1  5.2  0.1  4.9  1.6  0.0  0.0  3.9  0.0 20.8 11.9
## [3697]  0.2  0.0  0.0  0.0  0.0  0.1  0.0  0.0  1.0 10.1 13.8  5.1  0.0  0.3
## [3711]  0.0  0.0  0.0  0.0  0.0  0.0  1.4  1.6  0.0  0.0  0.0  0.0  2.0  9.5
## [3725]  0.6  0.0  0.0  0.1 11.8  0.0  0.1  0.0  3.1  1.0  0.0  0.0  1.8  0.0
## [3739]  0.0  0.4  0.0  0.0  0.0  2.4  0.0  1.0  6.7  5.0  0.0  0.1  0.3  0.0
## [3753]  0.0 28.1  0.0 21.6  0.0  8.6 37.9  6.0  0.3  0.0 13.2  0.2  0.0  0.0
## [3767]  0.0  0.1  6.7 11.0  0.0  0.0  0.0  0.1  0.0  1.8  5.1  0.0  3.9  6.7
## [3781]  9.3 12.8  3.8  0.0 29.6  2.5  0.0  2.7  0.8  4.1  0.0  0.0  0.0  1.0
## [3795]  2.8  5.2  5.6  0.0  1.7  2.1  5.7  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [3809]  0.0  0.0  0.0  0.0  2.8  0.0  0.0  0.0  9.1 42.2 18.0  0.0  0.0  0.0
## [3823]  0.0  0.9  0.2  0.0  0.0  4.9  0.0  0.0  0.0  0.0  0.0  0.0  0.6  0.0
## [3837]  1.5  2.9 13.5  0.0  0.0 27.8 15.2  0.0  0.0  3.7  0.0  0.0  0.0  0.0
## [3851]  6.4 53.7 17.0  1.6  0.0  0.1  3.0 18.5  2.9  0.0  0.0  0.3  0.0  8.5
## [3865]  0.1  0.0  0.7  9.8  9.6  7.0  0.0  0.0  7.5 21.6  5.1  0.0  6.3 27.0
## [3879] 15.0  0.0  0.2  0.7  0.0  0.0  0.0  0.0  0.0  0.0  0.0 17.7  0.4  8.6
## [3893]  0.0  4.9  0.0  0.1  0.0  0.0  0.0  0.0  0.0 10.2  1.2  2.4  0.1  0.0
## [3907]  0.0  0.0  0.0 11.0  0.0  0.7  7.1  0.8  0.0  0.0  3.6  0.2  0.0  0.0
## [3921]  0.0  0.0  0.0  0.3  5.1  1.2  4.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [3935]  0.0  0.0  0.1  0.5 21.3  3.2  3.5  2.4  3.9  0.0  0.0  0.0  0.0  0.0
## [3949]  0.0  0.0  1.0  0.0  0.0  0.0  0.0 25.6  0.9  0.0  0.0  2.8  0.0 11.3
## [3963]  1.4  0.0  0.0  0.0  4.5  0.3  0.0  0.0  0.0  1.7  0.0  0.0 11.7  0.0
## [3977] 13.3 20.1  0.0  0.0  0.0  2.7  1.6  0.0  0.0  0.0  0.0  0.0  0.0 14.4
## [3991]  2.4  0.0  0.8 13.2  0.0  0.0  0.2  0.0  2.3 11.3 23.2  1.2  2.1  0.4
## [4005]  4.2 18.5  6.0  5.3  1.8  8.8  0.3  0.0  0.0  0.0  0.0  0.0  6.5  5.9
## [4019]  1.7  2.5  0.0  0.0  1.8  0.0  0.0  0.1  1.9  0.0  0.0  0.0  1.4  0.0
## [4033]  0.0  0.0  0.0  3.7  0.0  0.0  0.0  0.0  1.1  0.0  1.8  0.8  0.0  4.1
## [4047]  0.0  0.0  0.0  0.0  0.0  7.8  0.0  0.0  0.0  0.8  3.7  0.0  0.9  0.0
## [4061]  0.0  0.0  0.0 16.0  1.1  0.0  0.0  0.0  0.8 39.4  0.0  0.0  0.3 12.1
```

```
## [4075] 46.6 13.0  0.0  0.1  0.0  9.3  0.0  0.0  0.9  0.0  0.0  0.0  0.0  0.0
## [4089]  0.0  2.6  8.2  0.0  2.5  1.5  2.1  0.0  0.9  0.1  0.0  0.0  5.4  0.0
## [4103]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.6  0.0  0.0  0.0  0.0  5.7 10.0
## [4117]  0.0  2.9  2.8  0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.0  0.0  0.1  2.3
## [4131]  0.0  0.0  0.0  0.2  7.7  0.0  0.0  0.0  9.3 11.9  0.6  1.0  0.5  0.0
## [4145]  0.0  0.0  0.0  0.0  0.0  1.4  0.0  0.0  0.0 15.6 17.5  6.1  2.5  1.8
## [4159]  0.0  1.1  6.4  6.3  0.0  0.0  0.0  2.0  0.0  2.7  4.9  0.2  0.0  0.0
## [4173]  6.1  0.0  0.0  0.0  0.8  0.0  1.8  4.1  0.2  0.0  0.0  0.2  0.0 12.0
## [4187] 15.0  0.0  0.0 13.9  0.0  0.0  0.1  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [4201]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0 35.2  4.5 13.6  0.0  1.5
## [4215] 15.3  2.3  7.9  1.6  0.0  0.0 24.6 20.1 13.5  0.1  2.1  0.0  0.0  0.0
## [4229]  0.1  0.0  7.1 11.5  0.7  0.8  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [4243]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [4257]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  5.5  0.0  0.5  0.1  6.6  1.6
## [4271]  1.5  0.0 11.9  0.1  0.0  0.0  0.0 18.3 17.1  3.2  3.5  7.0  2.0  0.2
## [4285]  0.0  5.1 11.2  1.2  0.0  0.0  0.0  3.1  0.0  0.0  0.0  0.0  0.0  0.0
## [4299]  0.0  0.3  1.8  9.3  0.2  0.0  0.0  0.0  5.9  2.1  0.1  0.4  0.0  0.1
## [4313]  0.0  0.0  0.0  0.0  0.0  0.0  1.1  5.8  1.4  8.0  0.4  0.0  0.0  0.0
## [4327]  0.0  4.1  0.8 17.7 11.8  2.0  4.9  0.3  0.0  0.2  7.7  0.0  0.0  0.0
## [4341] 19.7  1.0  0.2 26.3  8.0 11.1  0.6  0.2  5.8  0.0  0.0 17.3  1.4  0.0
## [4355]  0.0  0.5  7.4  2.2  0.0 21.0 20.6 14.2 10.0  0.0  0.0  3.8  2.6  0.0
## [4369]  0.0  0.0  0.0  0.0  2.3  0.0  0.0  0.0  0.0 10.9  1.5 17.4 11.2  8.0
## [4383] 12.8 59.2  0.0  0.0  0.0  0.0  0.0  0.0  4.4  0.0  2.0  0.0  3.7  0.2
## [4397]  0.0  0.0  0.1 17.9 33.1  9.1  4.1  3.9  1.1  2.2  1.2  0.0  0.0 10.4
## [4411] 14.1  4.1  1.0  0.4  0.0  0.0  0.0  0.0  0.0  0.0  3.3  7.5  6.9  0.3
## [4425]  0.0  0.0  0.2  0.0  0.0  2.1  4.0 16.8  0.5  8.9  0.6  0.0  0.0 14.8
## [4439]  5.4  0.2  2.2  2.6  0.0  0.0  6.8  1.5  1.8  0.2  1.9  1.2  7.8  1.7
## [4453]  6.0  3.0  2.0 35.2  1.0  0.0  0.0  0.0  0.0  0.0  8.9  0.7  0.0  0.8
## [4467]  0.0  0.0  0.0  0.0  4.0  0.0  0.0  0.0  2.2  4.0  1.2  0.0  0.0  0.0
## [4481]  0.0 31.6 61.6  6.8  2.0  2.6  0.0  0.1  4.3  0.0  0.6  5.8  0.0  0.0
## [4495]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.5  0.0  0.0
## [4509]  0.0  0.0  0.0  7.7  1.9  0.3  0.0  0.0  0.0  2.1  1.0  0.0  4.3  5.4
## [4523]  6.6  0.6  2.2  0.0  0.0  0.0  3.3  0.0  2.9  0.0  0.0 13.6  0.0  0.0
## [4537]  0.0  0.0  0.2  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.1 20.7  1.5
## [4551]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [4565]  0.0 10.0  1.0  2.5  0.0  0.6  0.3  0.0  0.0  0.8  0.0  2.3  4.6  0.0
## [4579]  9.9  0.0  0.0  0.0 22.1  7.4  3.6  8.7  0.8  0.3  0.0  2.0  5.4  7.0
## [4593]  8.5  1.1  1.8  0.0  0.0  0.0  0.0 14.3  0.3  0.0  0.0  0.0  5.0  6.8
## [4607] 19.4  5.1  0.1  0.1  0.0  0.0 33.3  2.7  1.2  8.4  0.3  2.9  0.0  0.0
## [4621]  3.0  0.7  1.9  4.9  7.5  6.3 16.8  7.5  0.0  4.7  6.8  0.0  0.2  1.7
## [4635]  2.4  7.1 14.4  7.7  1.5  0.0  0.0  0.4  2.7 19.2  0.4  0.0  0.0  0.0
## [4649]  9.6  2.9  0.0  0.0  0.0  0.0 16.1  0.0  0.0  1.1  0.0  0.0  0.0  0.0
## [4663]  0.0  0.0  0.0  0.0  3.8  7.5  0.0  0.0  1.1  0.3  0.0  0.0 69.1  2.5
## [4677]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  9.9  3.0  0.0  1.5  1.6
## [4691]  0.1  0.0  0.0 19.4  1.3  0.0  0.0  2.9  9.4 11.8  0.0  0.0  0.0  0.0
## [4705]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  4.5  0.4  0.0  0.0 10.9  0.1  0.7
## [4719]  5.8  0.0  0.0  0.0  5.7 21.7  0.0  0.0  0.0  0.0  0.0  0.0  0.1  0.8
## [4733]  0.4  1.1  0.0  0.0  0.0 13.7  3.5  0.1  4.1  0.0  5.9 11.8  3.6  0.5
## [4747]  0.7  0.5  0.0  0.0  0.0  0.0  0.0  0.6  0.0  0.0  0.0  8.6  0.0  9.3
## [4761]  3.4  0.8  0.0  0.0  0.0  0.0  0.0  1.5  0.0  0.0  0.0  8.0  0.0  0.0
## [4775]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  6.5  0.0  0.0  0.1  1.4  0.0
## [4789]  2.1  0.1  0.9  0.2  1.8 14.5 11.2 14.3  0.0  0.1  0.0  0.0  6.2  0.0
## [4803]  0.0  1.0 42.5  0.5  0.0 15.6 22.9  2.5  1.4  0.0  0.0  0.0  1.7 17.0
## [4817]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.1  3.0  0.0  2.6  0.3
```

```
## [4831]  0.0  0.0 17.4  2.2  6.8 18.7 25.5 10.5  0.0  0.0  0.0  0.0  4.6  0.5
## [4845]  0.0 11.4  0.2  6.8  4.8 32.0  5.2  0.3  0.0  0.0  0.0  0.0  1.0  0.0
## [4859] 14.4 26.0  0.0  0.0  8.9 19.2  0.0  0.0  0.0  0.0  0.3 10.4  8.9  0.0
## [4873]  0.0  2.5  6.3  2.2  0.0  0.0  0.0  0.0  0.4  0.0  6.4  1.2  0.2  0.0
## [4887]  0.0  7.7  0.0  0.0  0.0  0.0  0.0  0.0 12.1  0.1  0.0  0.1  1.6  7.1
## [4901] 10.2  5.3  0.0  0.0  6.9  1.3  0.0  0.0  0.0  0.0  0.2  0.1  0.0  0.0
## [4915]  0.1  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.3  0.0  0.0  0.0  7.2
## [4929]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.1  6.8  0.1  0.0  0.0  0.0
## [4943]  0.0  0.0  0.0  8.9  0.0  0.0  0.0  0.0  0.0 37.1  0.0  0.0  6.0  0.3
## [4957]  0.0  0.3  0.0  0.0  0.0  0.0  0.0 69.1  0.0  0.0 11.8  0.0  0.0 13.2
## [4971]  2.8  1.0  1.8  1.4  0.1  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [4985]  0.0  0.1  0.0  5.7  0.1  1.6  1.0  0.2  0.0  4.5  8.7  0.0  0.0  5.2
## [4999]  2.2  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  1.5  8.2
## [5013]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.1  4.2  9.3  0.1  0.7  0.0
## [5027]  0.0  7.3  2.5  0.0  2.3 19.5  0.1  0.0  0.2  0.8  0.1  8.5  0.0  0.0
## [5041]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.8  5.2  0.2  2.8
## [5055]  0.0  0.0  0.0  0.0  0.1  0.0  0.0  0.1  1.7  0.0  9.1  6.1  0.4  0.3
## [5069]  7.6  0.3  0.2  0.0  6.5  0.0  0.0  0.0  0.0 20.5  0.1  4.9  2.4  7.6
## [5083]  3.9  0.0  3.2  0.0  0.0  0.0 21.3  0.0  0.0  0.0 21.8  2.0  2.6  0.0
## [5097]  0.0  0.0  0.0  0.0  0.0  0.0  9.4 11.0  0.1  0.0  9.7  0.0  0.0  0.0
## [5111]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  1.9  0.7  0.3  0.0  0.0  8.3  0.0
## [5125]  7.3 14.2  0.2  0.0  0.0  2.5  0.0  0.0  0.0  0.0  0.4  2.1  0.0  0.0
## [5139]  0.6  0.0  0.0  0.0  0.0 20.5  8.2  2.2  0.0  0.0  0.0  0.0  0.2  0.7
## [5153]  8.9  9.5  5.5  1.9  0.2  0.2  0.0  0.0  6.5  8.0  0.6  0.0  0.0  0.0
## [5167]  0.3  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [5181]  0.0  0.0  0.0  0.0  0.0  7.6 31.4  0.0  0.0  0.0  0.0  0.1  0.0  0.1
## [5195]  0.0  0.0  0.0  5.5 11.2  0.0  0.0  0.0  0.0  7.4  0.0  0.0  0.0  0.0
## [5209]  0.0  0.0  0.0  0.7  0.0  0.0  0.0  7.5  0.0  0.0  0.0  1.5  0.7  0.2
## [5223] 17.4  3.8  0.0  0.0 34.7  1.9  1.2  0.4  2.4  0.0  0.0  6.4  0.2  7.1
## [5237]  0.0  5.3  0.0  2.6  0.0  0.0  0.0  0.0  0.1 16.8 12.9  0.4  5.7 22.7
## [5251]  1.6  6.7  0.2  0.0  0.0 18.9 18.5 16.0  7.2 15.8  3.4  9.1 13.8  0.2
## [5265]  0.0  0.8  0.5  0.8 18.0  0.0  0.0  0.0  0.0  2.4  0.0  0.0  0.0  0.0
## [5279]  1.2 19.1  5.9  0.0  0.0  0.0  0.0  0.0  6.1  0.0 23.8  7.7 22.5  0.0
## [5293]  0.3  0.8  3.3  7.6  1.1  2.2  0.0 14.7  0.0 18.3 11.1  0.0  0.3  0.0
## [5307]  0.0  0.0  0.0  0.1  0.0  0.0  1.9  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [5321] 17.2  0.1  0.0  0.0  0.0  3.3 16.9 22.1  3.1  2.0  7.8  0.1  0.0  0.0
## [5335]  0.0  0.7  0.0 35.5  3.5  0.4  1.9  0.0  0.0  0.0  0.0  1.9  9.0  0.1
## [5349]  1.4  0.0  1.0  0.6  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [5363]  1.9  1.5  0.7 16.4  9.3  3.4  1.2 14.3  0.2  1.9  0.3  0.0  0.0  0.5
## [5377]  0.0  3.1  5.4  1.9  0.0  0.0  0.0  0.0  0.0  0.0  0.0 22.8  1.4  0.0
## [5391]  0.0  3.5  0.0  2.9  0.0  0.0  0.6 14.0 11.3  0.0  0.0  0.0  0.0  0.0
## [5405]  0.0  1.4 11.0 22.2  0.0  0.0  0.0  6.7  0.0  0.0  3.9 25.5  0.0  0.0
## [5419]  0.0 14.5  0.2  0.0  0.0 21.0  0.0  0.0  0.0  0.0 11.2  0.0 10.7  0.7
## [5433]  1.7  2.1  0.0  0.0  2.6  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [5447]  0.0  0.0  1.3  0.0  0.0  0.0  1.1 14.0  0.0  0.1  0.0  4.5  4.8  0.0
## [5461]  0.0  0.0  0.6  2.9  5.4  0.6 10.9  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [5475]  0.0  0.0  0.0  0.0  1.8  0.0 11.5  0.0  0.0  0.0  0.0  0.0  5.1  3.4
## [5489]  0.5  0.0  0.0  0.0  8.6  0.9 15.1  1.9  0.0  0.8  0.1  0.0  0.4  0.0
## [5503]  0.0  0.0  0.0  0.0  0.0 10.7  0.0  4.3  0.0  0.0  0.0  0.3 12.7  1.3
## [5517]  0.0  0.0  0.0  6.7  9.9  3.9  1.6  9.8  0.0 12.5 16.8  5.1  4.2  0.0
## [5531] 14.0  0.7  0.0  0.0  0.0  6.8  3.3 35.7 21.7  0.7  5.2  0.0  0.0  0.0
## [5545]  0.1 22.2  0.0  2.5 18.1  0.0  0.0 11.6  0.0  7.7  0.0  0.0  0.0  0.6
## [5559]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [5573]  0.0  0.0  4.4  0.0 19.7  9.9  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
```

```
## [5587]  0.0  0.0  0.0  0.0  0.0  0.0  0.6 12.2  0.0  2.6  0.0  0.0  0.0  0.0
## [5601]  0.0  0.0  0.0  0.0 14.2  0.1  0.0  0.0  0.0 27.3  0.6  0.0  6.3  1.3
## [5615]  0.0  5.3  9.6 11.9  1.2  7.8  0.0  0.0  2.8  0.0  0.0 23.1 35.6  7.1
## [5629]  1.3  0.0  2.0  0.0  0.9  0.0  0.0  0.0  4.8  0.4  5.6  1.1  0.0  0.0
## [5643]  0.0  0.0  0.0  0.0  4.6  8.1  0.0  0.0  0.0  0.0  2.3  1.7  1.3  0.0
## [5657]  0.9  5.0  0.0  0.3  0.0  0.0  0.0  0.0  0.9  3.2  1.4  0.0  0.0  0.0
## [5671] 29.9  6.7  0.0  0.0  0.0  0.0  0.0  0.0  1.5 20.8  0.0  0.0  0.0  0.9
## [5685]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  7.2  0.0  0.4  0.0  0.0
## [5699]  0.0  0.0  0.0  0.0  0.0 13.7  4.1 13.0 12.5 23.0  7.1 13.1  0.9  0.1
## [5713]  3.1  1.8  0.0  0.0  0.0  0.0  0.0  0.0  0.2  1.3 12.9  0.0  0.0  0.0
## [5727]  0.7  0.0  0.0  0.0  0.0  0.0  2.1  9.4  1.8 10.0  5.3  1.7 12.4  1.1
## [5741]  0.0  0.0 15.3  6.0 12.4  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0 10.2
## [5755]  3.5  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  3.9  0.0  3.2  0.0
## [5769]  0.0  0.0  0.0  0.0  3.8  1.2  0.0  0.0  0.0  8.2  0.0  0.0  0.0  0.0
## [5783]  0.0  0.0  0.2  2.9  0.2  0.0  0.0  0.0  0.0  0.0  7.8  0.0 30.3  2.1
## [5797] 10.7  0.9  0.0  0.0  0.0  0.0  0.0  5.1  5.4 15.4  0.5 10.2  2.7  0.2
## [5811]  0.0  0.5  0.0  7.6  4.3 11.9  6.0  4.8  0.0  0.0  0.0  0.0  0.0  0.5
## [5825]  0.4  1.9  0.0  0.0  0.0 13.6  0.0  0.0  0.0  3.1 21.1  8.5  5.0  0.3
## [5839]  0.7  1.7  5.6  0.3  0.0  0.9  0.0 18.6  0.0  0.0  0.4  4.9  0.0  0.0
## [5853]  0.0  0.0  3.7  0.0  0.0  0.0  0.0 14.0  0.2  0.0  0.0  0.1  0.0  4.5
## [5867]  0.0  0.0  0.0 18.3 14.7  0.0  0.0  0.0  0.0  0.0  0.0 13.7 30.2  3.3
## [5881]  3.4  3.5 21.1  0.2  0.0  0.0  0.0  0.0  4.3  4.2 10.2  0.3  0.2  0.0
## [5895]  9.3  0.0  0.5  0.2  0.0  0.0  0.0  0.0  0.0  0.0  0.7  4.3  0.5  0.0
## [5909]  0.0  0.0  0.5  7.3  0.0  2.5  0.0  0.0  0.0  0.0  0.0  0.0  3.4  0.0
## [5923]  0.0  0.0  3.4  0.0  0.0  0.0  0.0  0.0 19.4  0.0  0.0  1.3  2.7  6.5
## [5937]  1.2  0.0  0.0  0.0  0.0  1.2  0.0  0.0 21.3  0.0  1.6  0.0  2.1  0.0
## [5951]  0.0  0.0  0.0  0.0 43.5  0.3  0.0  0.7  4.1  0.0  0.8  0.0  0.0  0.0
## [5965]  1.1  0.0  0.0  0.0  1.8  0.0  4.2  6.2  0.0  0.0  0.0  0.0  0.0  0.1
## [5979] 48.7  7.5  0.3  2.6  0.4  3.7  0.0  0.0  8.3  0.0  4.3  0.6  8.0 15.7
## [5993]  0.0  0.0  0.0  0.9  0.2  0.0  0.0  0.5  0.0  0.6  0.0  0.0  0.0  0.0
## [6007]  0.0  0.0  0.0  1.7 13.0  2.8  0.0  0.0  0.0  0.0  0.0  0.0  4.3  0.5
## [6021]  0.0 14.5  1.5  7.1  4.4  0.0  0.0  0.0  0.0  0.0  0.3  0.0  0.0  0.0
## [6035]  3.4  0.0  0.0  0.0  0.0  0.1  0.0  0.0  0.0  0.0  0.0  0.2  7.2 23.9
## [6049]  0.1  1.2  3.3  1.5  0.1  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.8
## [6063]  0.8  1.1  6.9  1.0 10.6  6.1  1.5  0.0  0.0 14.2  2.0  0.0  0.0  0.0
## [6077]  0.0  0.0 54.2  1.2  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [6091]  0.8 17.8  4.5  2.3  0.0  0.0  0.0  0.0  0.0  0.0  2.1  0.0  0.0  0.0
## [6105]  2.6 29.5  1.6 44.4  5.3  0.4  0.2  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [6119]  0.0  0.0  0.0  0.0  0.0  2.4  0.0  0.0  0.0  9.1  0.7  0.0  0.0  0.0
## [6133]  5.3 22.5  2.9  0.0  5.6  4.6  6.0  0.0  0.0 18.3 10.5  6.1  1.0  0.0
## [6147]  0.0  0.0  0.0  0.0  0.4 13.5 15.0  1.6  6.8  1.6  0.0  0.0  2.7  1.2
## [6161]  0.0  0.0  0.0  2.0  0.2  2.0  0.0  0.0  0.0 16.8  1.7  0.0  0.0  0.0
## [6175]  5.3  4.5  1.6  0.0  2.5  0.0  0.0  1.3  1.7 49.6  1.7  3.2  4.7  3.8
## [6189] 17.3  3.8  0.9 30.8  0.6  4.0 11.3  4.7  5.6  4.3  2.7  0.2  0.0  0.0
## [6203]  0.9  8.0  3.8  6.7 14.0  0.1  0.0  3.9 25.0  0.8  5.7  0.0  2.6  3.1
## [6217] 19.9  8.8  0.1  0.0  0.0  0.0  0.0  0.8  5.2  0.2  0.0  0.0  6.8  0.0
## [6231]  0.0  0.0  0.0  0.0 13.1  0.0 20.1  0.0  0.0 27.9  0.4  0.0  0.0  0.0
## [6245]  0.0  0.0  0.0  0.0  4.6  0.4  4.7 18.4  1.0  2.2  0.0  0.0 12.1  5.9
## [6259]  0.1  0.0  3.8  0.6  0.0  0.0 15.2  1.2  1.3  0.5  4.9  4.0  0.0  0.0
## [6273]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  2.4  5.9 11.7  0.0  0.0  0.0 11.6
## [6287]  0.5  6.0  0.0  0.0  0.0  1.0  0.0  0.7  0.0  0.0  0.0  1.8  0.0  0.0
## [6301]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  5.9 33.1  0.4  0.0
## [6315]  0.5  0.0  4.7 19.5  0.1  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [6329]  0.6  0.0  0.0  0.0  0.4 10.4  0.0  0.0  8.8 12.3  0.0 10.0  0.0  0.0
```

```
## [6343]  0.0  0.0  0.0  0.0  0.0  2.9  9.4  4.5  1.0 15.3  1.0 14.4  3.3  0.0
## [6357]  7.4  0.0  0.0  1.3  0.0  0.0  0.0  0.0  0.0  0.0  4.7  0.7  0.0  0.0
## [6371]  0.0  0.0 16.1 11.4  0.0  0.2  0.0  0.0  0.0  0.0  0.7 20.4  4.5  2.5
## [6385]  0.0  1.1 10.8  2.9  5.7 31.9  0.0  0.0  0.0  0.0  0.4 14.9  0.7  0.0
## [6399]  0.0  0.0  0.0  0.0  0.0 47.9  0.0  0.0  0.0  0.0  0.0  0.4  1.7  0.2
## [6413]  4.8 16.4  2.9  2.2 21.4  1.4  3.0  0.3  0.5  3.4  0.0 11.3  0.0  6.1
## [6427]  5.2  0.0  0.0  0.0  0.2  0.0  0.0  1.8  0.0  2.9  0.0  0.0  0.0  0.0
## [6441]  0.0  0.0  7.7 21.9  1.1  0.0  0.0  0.0  0.1  3.4  0.0  4.0  2.2  0.0
## [6455]  0.0  0.0  0.0  0.0  0.0  0.0  0.1  0.1  2.3  0.0  0.0  1.2  1.5  0.0
## [6469]  0.0  4.6  0.4 17.8  4.0  0.0  1.2  4.2  0.0  4.7 14.1  1.2  0.0  6.2
## [6483] 14.1 12.2  0.3  0.0  0.0  0.0  0.0  0.0  0.0  0.9  0.0  0.5  0.0 10.9
## [6497]  4.3  8.6  0.0  0.0  0.0  1.4  0.3  0.7  8.0  1.3  0.0  0.0  0.0  0.0
## [6511]  0.0  0.0  0.0  0.0  0.0  0.6  1.2  4.1  0.0  3.7 27.8  0.0  0.0  0.0
## [6525]  0.0  7.4  2.1  0.0  0.0 23.7  5.2  0.0  9.2  1.3  0.0  3.9  6.2  0.0
## [6539] 20.7 19.2  2.3  0.0  0.0 14.1  0.0 10.7 18.6  2.7  0.2  0.0  0.0  0.0
## [6553]  0.0  0.0  0.0  0.0  0.0  8.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [6567]  1.6 11.0  1.7  0.0  0.3  0.0  9.4  3.1 13.0 32.5  0.0 12.7  0.3  0.8
## [6581]  0.3  0.0  0.0  5.8  0.0  0.0  0.0  0.0  0.0  1.1  0.0  0.0  0.0  0.0
## [6595]  4.8  4.0  0.0  5.0  0.9 31.9  9.7  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [6609]  2.2  1.6 15.3  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.2  0.0  8.0  4.5
## [6623] 11.5  0.0  0.0  6.2  0.1  7.0  0.4  0.0  6.6  5.8  0.0  0.0  0.0  0.0
## [6637]  0.0  0.0  0.0  0.0  0.0  3.6  0.0  0.0  0.0 45.9  1.3  0.0  0.0  4.2
## [6651]  0.0  0.0  0.0  0.2  0.0  7.2  0.0  1.3  4.2  0.0  0.0  0.6  1.6  0.0
## [6665]  7.9  4.2  0.2 22.3 13.5 10.2  2.5  0.0  0.0  4.8  0.0  0.0  0.2  0.0
## [6679]  0.0  0.0  0.0  0.0  2.8  2.7  7.5  8.6  6.7  4.5  8.7  6.8  0.0  4.3
## [6693] 10.0 24.2  1.9  0.1  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [6707]  0.0 19.4  0.0 16.4  0.1  0.0  0.0  0.0  6.2  0.0  1.2  0.0  0.0 11.3
## [6721]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.1  3.5  6.5  0.0  2.7  0.0  0.0
## [6735]  0.0  0.0  0.0  0.0  0.0  1.7  0.0  0.0  0.0  0.0 14.6  9.1  4.9  0.7
## [6749]  2.4  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.1  0.0
## [6763]  0.0  0.0  0.2 18.8  0.0  0.6  1.6  0.0  2.6 26.6  0.0  0.0 22.4  1.4
## [6777]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.4  1.3
## [6791] 20.0 10.6  1.7 41.3  0.0  8.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0 11.4
## [6805] 12.6 16.7  0.0 31.2 15.0  0.0  0.3  0.0  0.0  0.0  0.0  0.0  0.0 13.0
## [6819]  0.6  3.3  0.0  0.0  0.1  0.0  0.0  0.7  1.7  2.4  5.5  1.1  0.0  0.0
## [6833]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  4.9  5.8  0.1  1.1  5.0  6.5
## [6847]  2.0  3.0 11.4  0.0  0.0  0.0  0.0 40.9  0.7  0.3 23.9  6.4  2.9  0.6
## [6861]  3.9  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0 31.3  1.4  0.0  0.0
## [6875]  0.0  0.0  0.1 29.8  0.4 13.1  4.7  0.0  0.0  8.7 10.3  5.0 48.2  0.0
## [6889]  0.4  0.0 25.8 24.6  4.7  9.7  0.0  0.0  8.8  0.0  0.0  0.0  0.0  2.4
## [6903]  0.0  0.0  2.0  0.0  0.0  0.0  0.0  0.0  0.0 18.6  6.6  0.0  0.0  0.0
## [6917]  0.0  0.0  0.0  0.0  0.0  0.0  7.1  4.4  0.0  0.3  0.2  5.4  2.5  1.8
## [6931]  0.0  0.0  5.0  0.0  7.2  4.7  0.0  6.1  7.2  0.0  0.0  0.0  0.0  0.2
## [6945]  0.0  0.0  3.0  0.0  0.0  0.0  0.0  0.0  0.1  0.1  0.0  0.0  0.3  7.9
## [6959]  0.0  0.0  5.4 16.3  0.2  0.0  0.7  0.0  1.2  0.0  0.0  0.0  0.0  1.0
## [6973]  0.0  5.6  1.3  0.0  0.0  0.0  0.0  3.7 11.8  0.2  0.5  0.0  6.8  0.0
## [6987]  3.0  0.0  0.0  0.0  0.0  1.2  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [7001]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  7.2  3.3 11.2  0.0  0.0  0.0  0.0
## [7015]  1.3 15.7  0.0  6.4  6.2  0.0  0.0  0.0  0.0  0.0  2.7 11.7  0.4 11.5
## [7029]  0.0  0.0  0.0  0.0  0.4  8.7  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [7043]  2.4  0.4  0.0 18.6  7.8  0.0  8.5  0.0  0.0  1.5  1.5 11.9  8.8 12.3
## [7057]  0.6 13.1  0.0  0.0  0.0  0.0 16.9 11.0 19.9  3.4 10.4 22.7  6.7  0.0
## [7071]  0.0  0.1  0.0  0.0  0.0  0.3  0.0 12.1  1.1  8.5  7.8  1.3  0.0  4.6
## [7085]  0.0  0.0  0.0  0.0  0.0 18.1  0.0  0.0  2.5 12.8  1.8  0.2  3.6  9.1
```

```
## [7099]  0.0 45.1  2.0  1.0 22.9 22.2  4.0  0.0  0.0  9.2  5.1  0.4  0.0  0.0
## [7113]  0.0 11.9  4.6  6.7 31.3  1.0  0.1  0.0 20.6  6.3  3.9  9.4  0.0  0.0
## [7127]  0.0  0.0  0.0  0.0  0.0 11.5  1.0  6.9  0.0 26.5 10.1  0.0  0.0  0.0
## [7141]  0.0 19.2  0.0  0.0  6.6  4.5  0.0  0.0  0.0 15.5  7.9 78.5  7.7  2.9
## [7155]  0.0  0.1  0.0  0.1  0.6  4.2  0.8  0.0  3.3  1.4 21.7  0.0  0.0  0.0
## [7169]  0.9  0.0  0.0 26.4 87.3  5.8  0.0  0.0 14.0  1.4  0.5  0.0  4.1  3.2
## [7183]  0.0  0.0  0.0 15.9  2.9  0.0  0.0  2.4  8.4  1.9  0.0  0.0  0.0  0.0
## [7197]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.2  0.1  0.0 12.6 16.1  0.0  0.0
## [7211] 21.1  0.0  0.0  0.0  0.0 27.6 11.4 21.1  1.0  0.0  0.3  3.0  0.0  0.6
## [7225]  0.0  0.0  0.0  0.0  0.0  0.0  0.4  0.0  0.0  0.0  4.6  7.0 11.2  0.0
## [7239]  0.0  0.0  0.0  0.0  2.5  1.1  0.0  0.0 19.9 50.0  0.0  5.9  1.1  0.0
## [7253]  1.7  0.0  3.9  0.0  0.0  6.2  0.9  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [7267]  0.8  0.0  0.0  0.0  0.0 14.7  6.9  2.2  5.8  0.8  6.4  0.0  0.0  0.0
## [7281] 12.6 23.7  0.0  0.0  0.0  4.5  0.1  0.3  5.7  0.0  0.0  0.0  2.3  0.0
## [7295]  0.0  5.0  1.5  0.0  0.0  0.0  1.3  0.8  1.5  7.6  2.0  0.5  0.0  0.0
## [7309]  0.0  0.0 38.8  0.5 14.5 13.4  2.3  0.0  0.0  0.3  1.4  3.7  2.4  0.0
## [7323]  0.0  5.6  0.0  0.0  0.0  0.0  0.5  1.5  0.1  0.0  0.0  0.0 11.8 15.7
## [7337]  2.1  1.1  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [7351]  0.0  4.3  7.8  0.1  0.0  0.0  0.0  0.0  0.0  2.1  0.7  0.0  0.0  0.0
## [7365]  2.1  0.0  0.8  0.0  2.3  5.2  0.0  0.0  3.9  1.5 12.8  5.8  0.9  7.4
## [7379]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
## [7393]  0.1  0.0  0.0  0.0  0.0  0.0  1.4  0.0  1.5  0.2  0.0  0.0  0.0  0.9
## [7407]  0.0  0.0  0.0  0.7  1.8  4.3  0.0  0.0  3.5  0.0  2.5  5.2  2.7  0.0
## [7421]  2.2 19.3  0.0 12.2  1.8  0.0  0.0  0.6  0.0  0.0 17.9  5.0  0.0 31.5
## [7435]  7.1  4.7  0.0  0.4  0.0  1.5  0.0  0.5  3.8  6.4  0.0  4.0 12.1  0.0
## [7449]  0.3  7.2  0.0  0.6  0.0  0.0  6.1  9.6  0.0  4.9  8.1  0.2  1.7  0.0
## [7463]  0.0  0.0  0.0  0.0  2.2 10.0  5.4  0.9  0.0  0.0 11.7  0.0  0.0  0.0
## [7477]  0.0  0.0  0.0  1.7  0.0  0.0  0.0  0.0  0.0  0.0  0.1 20.2  0.0  1.5
## [7491] 11.5  0.0  8.3  8.7  0.0  0.0  0.9 29.8  0.3  2.9  1.3  7.6  8.0  4.5
## [7505]  0.0  0.0  0.0  0.0  0.3  0.2  0.0  0.0  0.0  0.1  3.4  0.9  1.9 21.6
## [7519]  0.2  0.2  0.0  0.0  0.0  1.0  0.0 16.2  0.9  0.0  0.3  1.9  0.5  0.0
## [7533]  0.0  0.0  0.0  0.0  0.1 15.7  0.5  0.0  0.0  0.0  3.9  0.0  3.1 21.4
## [7547]  4.0  0.0  1.4 18.7  6.5  0.0 12.4  9.1  5.8  1.1  0.0  0.0  0.0  0.1
## [7561]  0.0  6.3  6.3 17.3  0.0  0.0  1.5  2.2  2.5  0.0  0.0  0.0  1.3 25.7
## [7575]  2.4  0.0  2.8 37.8 12.0  1.7  0.5  0.0  3.3  0.0  0.0  6.6  0.7  2.1
## [7589]  0.0  0.0  0.0  0.0  3.2  0.5  0.0  0.0  0.0  0.0  0.0  0.1  3.6  3.2
## [7603]  0.0  0.0  0.0  0.0  0.0  6.8 20.9  1.5  0.0  0.0  0.0  0.0  0.0  0.0
## [7617]  0.0  0.0 12.7  2.3  0.0  0.0  0.0  0.2  0.8  0.0  7.7 15.2  3.5  0.0
## [7631]  0.0  0.0 15.3 21.6  3.4  3.9  0.0  0.0  0.0  0.0  0.0  0.0  1.0 31.0
## [7645]  5.5  0.0  0.0  5.2  0.0  0.0  0.0  0.0  0.0  0.0 29.8  0.0  0.0  1.3
## [7659]  1.5  0.0  0.0  0.0  1.8 12.6  0.0  0.0  2.9  4.8  0.0  0.0  0.0  0.0
## [7673]  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  2.0  5.1  0.0  0.0
## [7687]  0.0  2.3  0.0  0.0  0.0  0.0 55.8 43.9  0.0  0.0  0.0  0.0  0.0  4.4
## [7701]  0.0  5.7 20.9  0.2  0.0  0.0  0.0  0.0  0.0  0.0  0.0  1.7  0.0  2.8
## [7715]  0.1  0.0  0.0  0.0  0.0 23.4  2.0  0.0  1.6  0.5  0.0  0.0  0.0  0.5
## [7729]  0.0  0.0  6.4  0.0  0.0  0.0  0.0  0.0  0.7  0.0  0.0  0.0  0.0  0.0
## [7743]  0.0  0.0  0.0  0.0  0.0  0.0  0.0 28.7  2.7  0.0  0.0  0.0  5.9  6.3
## [7757]  0.0  1.1 14.6  0.0 28.1  0.2  3.1 14.6  7.6  4.7  8.0  0.2  1.4  0.3
## [7771]  1.7  0.0  0.0  0.0  0.0  3.4 12.5  9.4  6.1  0.0  0.0  1.2  4.4 10.2
## [7785] 18.0  0.6  2.4  0.0  1.5  1.3  1.1  0.0  0.0  0.0  3.6 11.1 10.1  8.0
## [7799]  5.6  0.2  8.3  3.9  5.0  2.0  0.0  0.4  0.0  0.0  0.0  0.0  1.7  0.0
## [7813]  6.1  6.6  0.0  0.2  0.6  0.0  0.0
##
## attr(,"class")
```

```
## [1] "gpd.fit"
```

```r
nu_hat <- gpd_fit$mle[2]
beta_hat <- gpd_fit$mle[1]
p_exceed <- mean(df$precip > th, na.rm=TRUE)
return_level_pot <- function(T_years){
  p_annual <- 1/(T_years*365)
  if(abs(nu_hat) < 1e-6){
    z <- th + beta_hat * log(p_exceed / p_annual)
  } else {
    z <- th + (beta_hat/nu_hat) * ( (p_exceed / p_annual)^{nu_hat} - 1 )
  }
  return(z)
}
cat('Approx 10-year return level (precip):', return_level_pot(10), '\n')
```

```
## Approx 10-year return level (precip): 71.34499
```

5 Declustering

Methodology

Use a simple runs declustering: within runs of consecutive exceedances keep only the maximum value. This reduces temporal dependence of peaks prior to tail modeling.

Results / Comments

The number of retained exceedances after declustering is printed and used as a diagnostic.

```r
decluster_runs <- function(dates, series, threshold, run_length_days = 3){
  idx_exceed <- which(series > threshold)
  if(length(idx_exceed)==0) return(integer(0))
  groups <- cumsum(c(1, diff(idx_exceed) > run_length_days))
  keep_idx <- tapply(idx_exceed, groups, function(idxs) idxs[which.max(series[idxs])])
  return(as.integer(unlist(keep_idx)))
}
kept <- decluster_runs(df$date, df$precip, th, run_length_days = 2)
cat('After declustering (run=2 days) kept exceedances:', length(kept), '\n')
```

```
## After declustering (run=2 days) kept exceedances: 342
```

6 Tail dependence and scatter

Methodology

Compute the empirical conditional probability P(discharge>q_d | precip>q_p) at high quantiles (95%) and display a scatter of top quantiles.

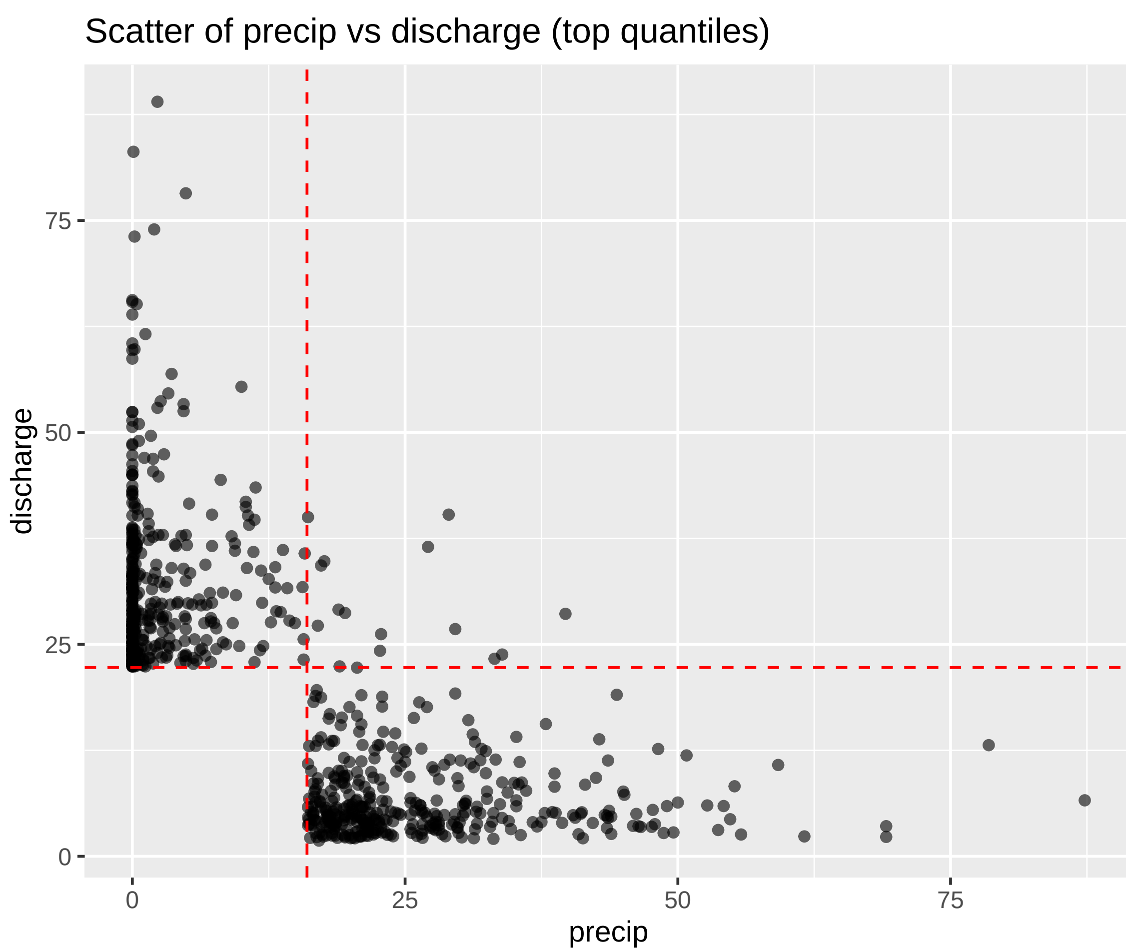
Results / Comments

This measure gives a quick, empirical look at tail association between high precipitation and high discharge on the same day.

```
q_p <- quantile(df$precip, 0.95, na.rm=TRUE)
q_d <- quantile(df$discharge, 0.95, na.rm=TRUE)
cond_prob <- mean(df$discharge > q_d & df$precip > q_p, na.rm=TRUE) / mean(df$precip > q_p, na.rm=TRUE)
cat('Empirical P(discharge>q_d | precip>q_p) at 95% quantiles:', cond_prob, '\n')
```

```
## Empirical P(discharge>q_d | precip>q_p) at 95% quantiles: 0.03836317
```

```
top_df <- df %>% filter(precip > q_p | discharge > q_d)
print(ggplot(top_df, aes(x=precip, y=discharge)) + geom_point(alpha=0.6) +
  geom_hline(yintercept = q_d, color='red', linetype='dashed') +
  geom_vline(xintercept = q_p, color='red', linetype='dashed') +
  labs(title='Scatter of precip vs discharge (top quantiles)'))
```



7 Extreme causality tests

Methodology

Source `JuroExtremes.R` and run the provided `Extreme_causality_test` for several future lags in both directions (precip→discharge and discharge→precip). We use bootstrap repetitions for stability.

Results / Comments

The causality test outputs indicate whether extreme precipitation precedes extreme discharge at the tested lags. Results are printed below.

```
helpers_path <- file.path('practical_1','JuroExtremes.R')
if(file.exists(helpers_path)){
  source(helpers_path)
} else stop('JuroExtremes.R not found')

common_idx <- which(!is.na(df$discharge) & !is.na(df$precip))
xseries <- df$precip[common_idx]
yseries <- df$discharge[common_idx]

res_list <- list()
for(lag_f in 0:3){
  res <- Extreme_causality_test(xseries, yseries, z = NULL, lag_future = lag_f, p_value_computation = FA
  res_list[[as.character(lag_f)]] <- res
  cat('Lag', lag_f, ':', as.character(res$output), 'CTC=', res$CTC, 'baseline=', res$baseline, '\n')
}
```

```
## Lag 0 : No causality CTC= 0.5188186 baseline= 0.3215919
## Lag 1 : No causality CTC= 0.4792721 baseline= 0.2583037
## Lag 2 : Evidence of causality CTC= 0.8267955 baseline= 0.3338323
## Lag 3 : Evidence of causality CTC= 0.8771856 baseline= 0.3926592
```

```
res_rev <- list()
for(lag_f in 0:3){
  res2 <- Extreme_causality_test(yseries, xseries, z = NULL, lag_future = lag_f, p_value_computation = F
  res_rev[[as.character(lag_f)]] <- res2
  cat('Reverse Lag', lag_f, ':', as.character(res2$output), '\n')
}
```

```
## Reverse Lag 0 : No causality
## Reverse Lag 1 : No causality
## Reverse Lag 2 : No causality
## Reverse Lag 3 : No causality
```

```
saveRDS(list(gev_fit=gev_fit, gpd_fit=gpd_fit, causality_precip_to_discharge = res_list, causality_rev =
```

Takeaways

- Discharge annual maxima were modeled with a GEV; model parameters and a 100-year return level are reported above.

- Precipitation extremes (POT) were modeled with a GPD using the 95% quantile as threshold; an approximate 10-year return level is provided.
- Declustering reduces clusters of exceedances; the retained exceedances are used for inference.
- Empirical tail-dependence at 95% shows a small conditional probability that large precip coincides with large discharge in the same day.
- The provided extreme-causality test suggests evidence of causality from precipitation to discharge at some positive lags (see outputs); the reverse direction showed no causality in this analysis.

Rendering to PDF

This RMarkdown is set to produce a PDF via the `pdflatex` engine. To knit to PDF from R you can run:

```r
rmarkdown::render('practical_1/Practical1_report.Rmd', output_format = 'pdf_document')
```

Note: producing PDF requires a working LaTeX installation (MiKTeX, TeX Live, MacTeX). A convenient lightweight option inside R is to install TinyTeX:

```r
if(!requireNamespace('tinytex', quietly = TRUE)) install.packages('tinytex')
tinytex::install_tinytex()
```

If LaTeX is not available, you can render HTML instead and convert to PDF later (or use the RStudio knit button which often helps resolve path issues):

```r
rmarkdown::render('practical_1/Practical1_report.Rmd', output_format = 'html_document')
```

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