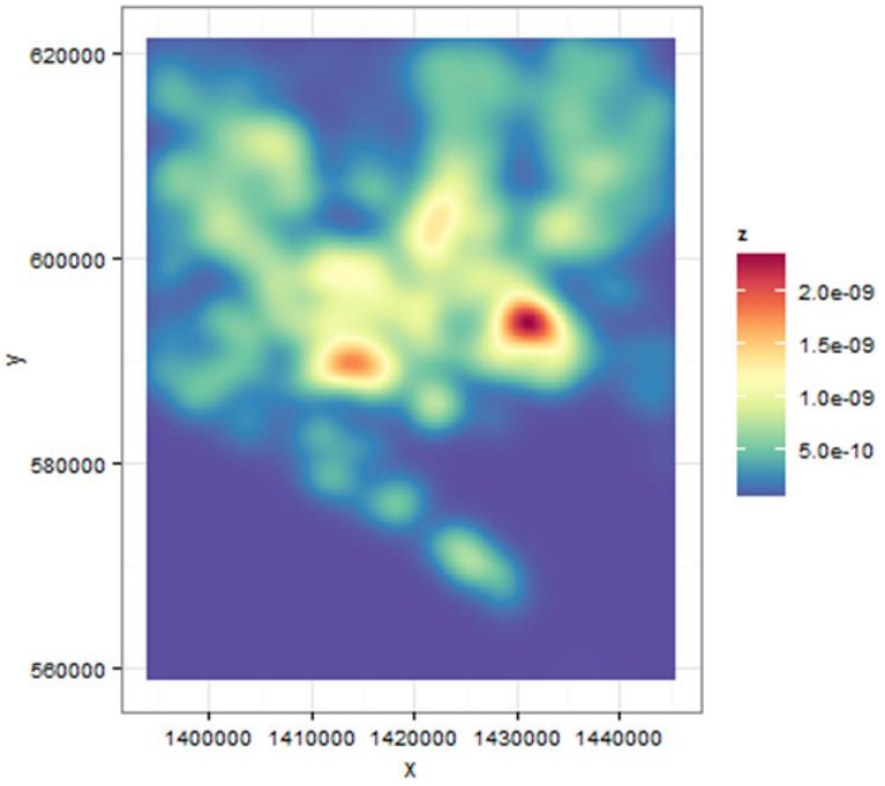
POINT PATTERN ANALYSIS

A Tutorial



DATA ANALYSIS & VISUALIZATION
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1. Introduction

A point pattern dataset gives the locations of objects/events occurring in a study region. The points may have information called marks attached to them. The marks represent an attribute of the point. The mark variable could be categorical or continuous. A dataset can also include covariates : any data that we treat as explanatory (rather than part of the response).

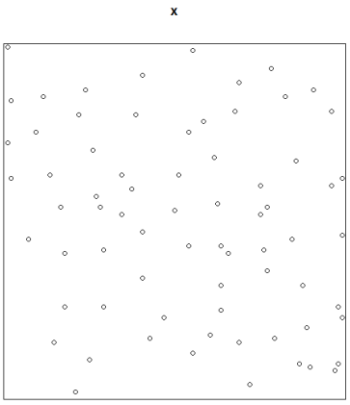
Intensity is the average density of points. Intensity may be constant (uniform) or may vary from location to location (non-uniform or inhomogeneous). Interpoint interaction refers to the dependence between the points in a point pattern. Usually we expect dependence to be strongest between points that are close to one another.

Data are often supplied with information about the sampling window W. It is important to know the window W, since we need to know where points were not observed.

2. Package SPATSTAT

For our first demonstration, we'll use the standard point pattern dataset that is installed with the package.

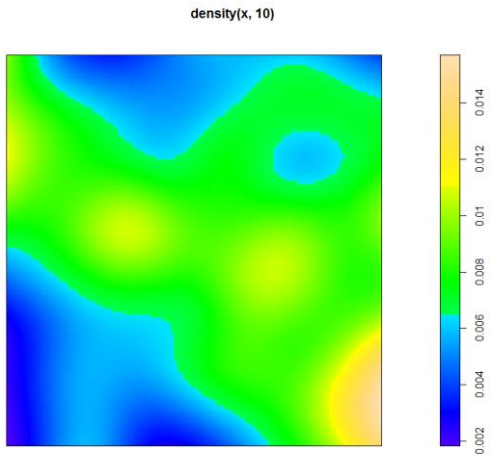
```
library(spatstat)
data(swedishpines)
x <- swedishpines
plot(x)
summary(x)
```

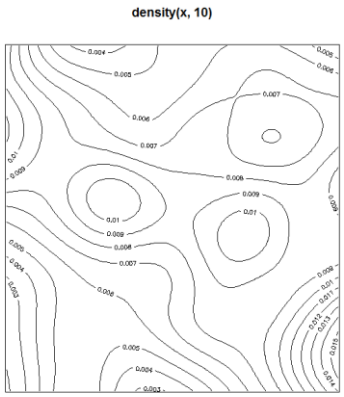



```
Planar point pattern: 71 points
Average intensity 0.0074 points per square unit (one unit = 0.1 metres)

Coordinates are integers
i.e. rounded to the nearest 1 unit (one unit = 0.1 metres)

Window: rectangle = [0, 96] x [0, 100] units
Window area =  9600 square units
Unit of length: 0.1 metres
```

Let's study the intensity (density of points) in this point pattern.

plot(density(x,10))
contour(density(x,10),axes=FALSE)



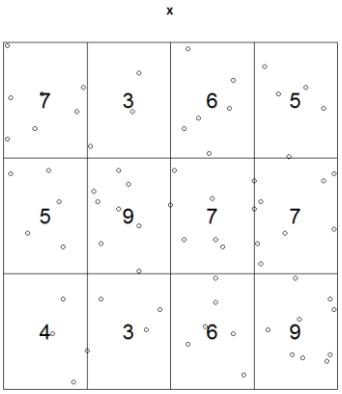


Spatstat is designed to support all the standard types of explantory data analysis for point patterns. One example is quatrad counting : the study region is devided into rectangles (quadrats) of equal size, and the number of points in each rectangle is counted.

q <- quadratcount(x,nx=4,ny=3)
q

```
             x
y             [0,24] (24,48] (48,72] (72,96]
  (66.7,100]      7       3       6       5
  (33.3,66.7]     5       9       7       7
  [0,33.3]        4       3       6       9
```

```
plot(x)
plot(q,add=TRUE,cex=2)
```

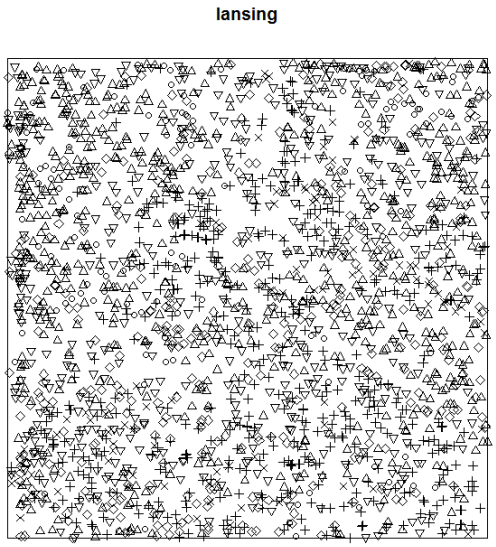


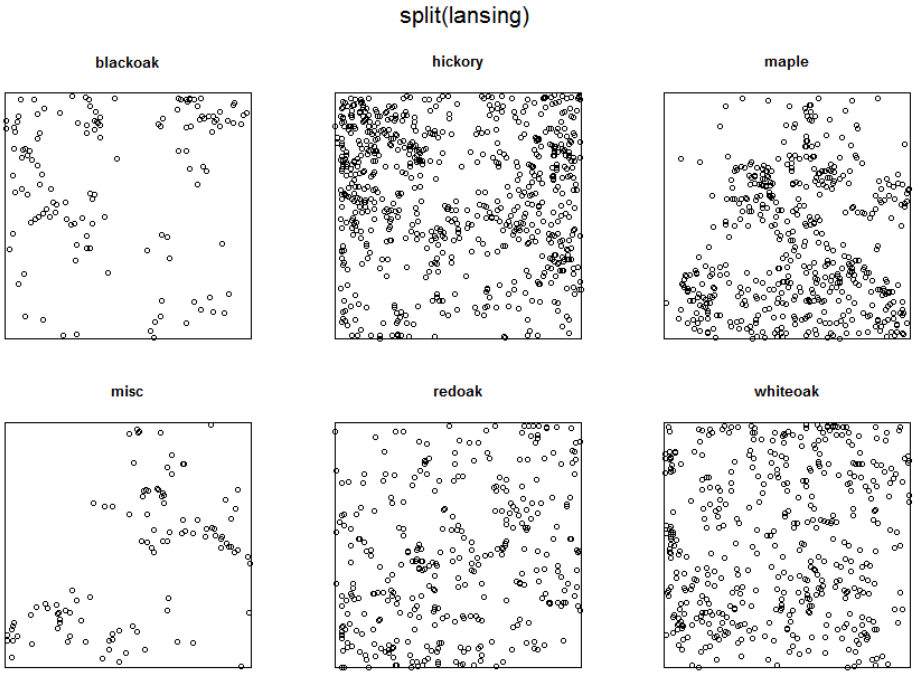
A marked point pattern in which the marks are a categorical variable is called a multitype point pattern.

```
data(lansing)
summary(lansing)
```

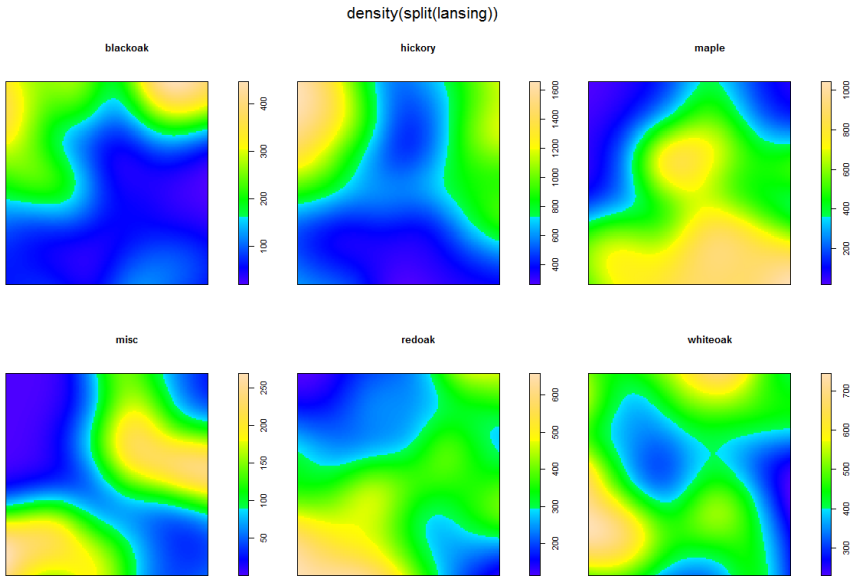
```
Marked planar point pattern: 2251 points
Average intensity 2250 points per square unit (one unit = 924 feet)

*Pattern contains duplicated points*

Coordinates are given to 3 decimal places
i.e. rounded to the nearest multiple of 0.001 units (one unit = 924 feet)

Multitype:
          frequency proportion intensity
blackoak        135     0.0600       135
hickory         703     0.3120       703
maple           514     0.2280       514
misc            105     0.0466       105
redoak          346     0.1540       346
whiteoak        448     0.1990       448

Window: rectangle = [0, 1] x [0, 1] units
Window area =  1 square unit
Unit of length: 924 feet
```

```
plot(lansing)
plot(split(lansing))
```

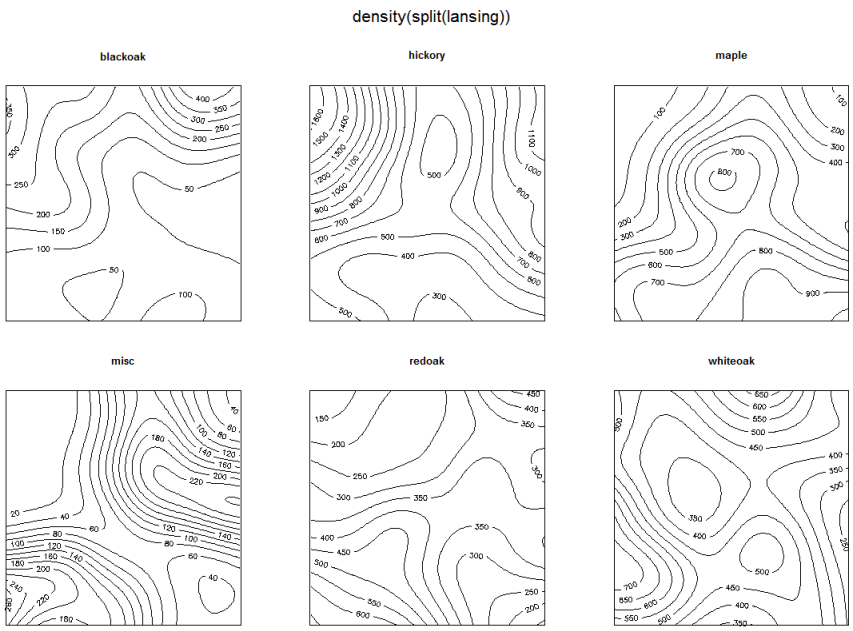




plot(density(split(lansing)))



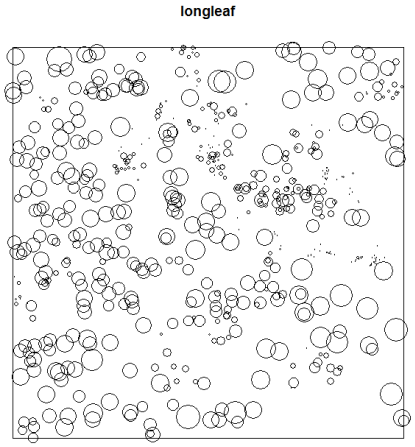
contour(density(split(lansing)),axes=F)

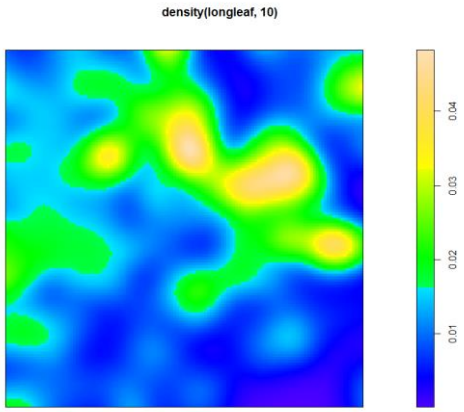


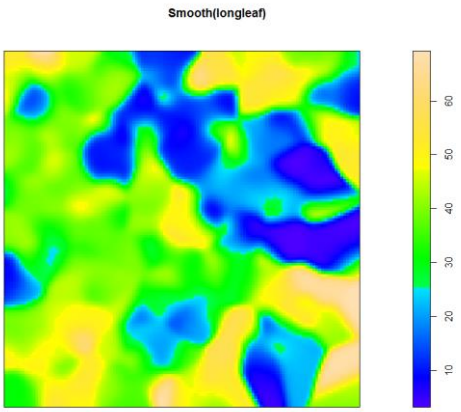
```
data(longleaf)
summary(longleaf)
```

```
Marked planar point pattern: 584 points
Average intensity 0.0146 points per square metre

Coordinates are given to 1 decimal places
i.e. rounded to the nearest multiple of 0.1 metres

marks are  numeric,  of type 'double'
Summary:
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
   2.00    9.10   26.15   26.84   42.12   75.90

Window: rectangle = [0, 200] x [0, 200] metres
Window area =  40000 square metres
Unit of length: 1 metre
```

```
plot(longleaf)
plot(density(longleaf,10))
plot(Smooth(longleaf))
```



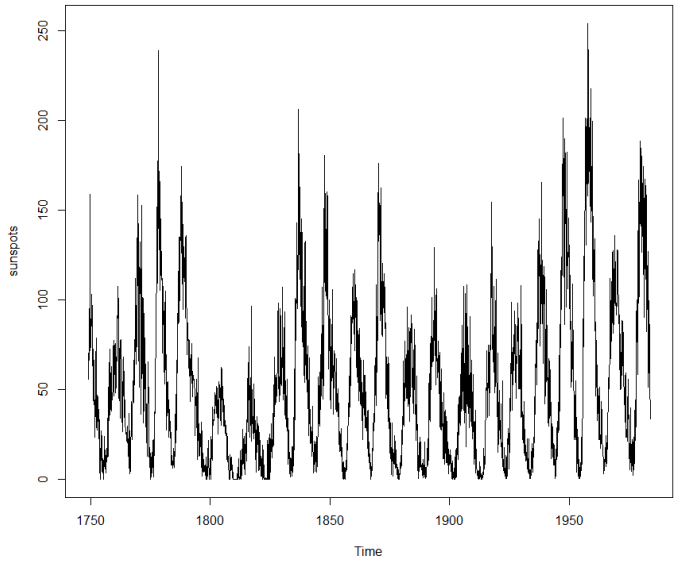




R is an object-oriented package. A dataset with some kind of structure on it (e.g. a table, a time series, a point pattern) is treated as a single object. Each object in R is identified as belonging to a particular type or class depending on its structure. Standard operations, such as printing, plotting or calculating the sample mean, are defined separately for each class of object.

For example, the sunspots dataset is a time series :

```
data(sunspots)
plot(sunspots)
```



Sunspots is an object of class “ts” representing time series, and there is a special “method” for plotting time series, called ”plot.ts”. The command “plot(sunspots)” is dispatched to the method “plot.ts”.

To handle point pattern datasets, the spatstat package defines the following classes of objects :

- ppp (planar point pattern)
- owin (spatial region (observation window)
- im : pixel image

To use spatstat functions, data must be read into R and then converted into on object of the appropriate format.

Spatial data is often stored in formats (e.g. ESRI shapefiles) that Geographical Information Systems (GIS) can handle. Spatstat does not support these formats. The package sp provides support for spatial data types in R. The usual procedure for converting spatial data is :

(1) reed the data in R using a package that is designed specifically for that file format (e.g. package maptools to read Esri shapefiles in R) ;
(2) convert this R dataset into a genereic format used by package sp ;
(3) convert the generic format to the required spatstat format, using package sp.

For example, if your window (spatial region) is supplied as an ESRI shapefile with a name "myfile.shp", then use the following commands :

```
library(maptools)
S <- readShapePoly("myfile.shp")
library(sp)
SP <- as(S,"SpatialPolygons")
W <- as(SP,"owin")
```

If your point pattern locations are supplied in an ESRI shapefile "mypoints.shp", than use the following command :

```
library(maptools)
S <- readShapePoints("mypoints.shp")
library(sp)
SP <- as(S,"SpatialPoints")
P <- as(SP,"ppp")
```

The result is a point pattern of class "ppp" in spatstat, but a correct window must be assigned to it. Point pattern objects need bounding windows to show where the population of data points ware collected. In spatstat, the observation window is an integral part of the point pattern. When you create a new point pattern object, you need to specify the spacial region or window in which the pattern as observed. A point pattern dataset consists of knowledge where points were not observed, as well as the locations where they were observed.

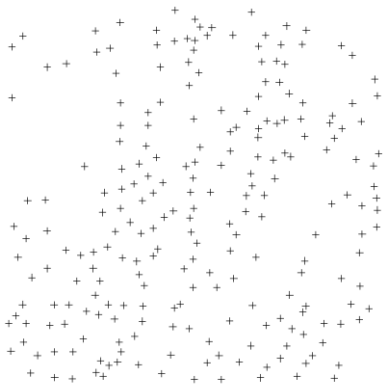
The default window is the bounding box of the points.
With the above example :

```
bb <- bounding.box(P)
W <- as(bb,"owin")
```

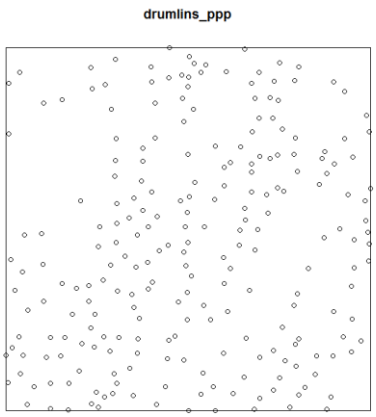
3. Point pattern analysis with R

We illustrate the analysis of point patterns through a series of real-world examples that make use of the "spatstat" package and various other functions included in R packages.

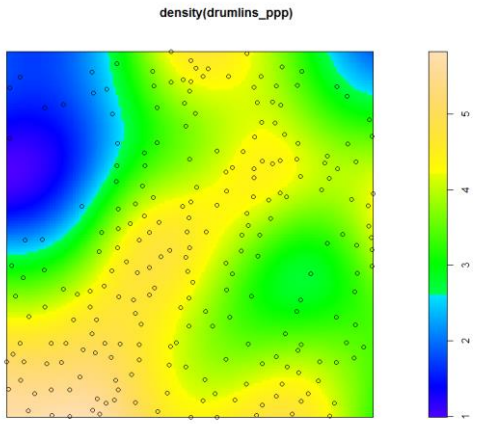
```
# Example 1 (Drumlins data)
# source data : spatialpoints shapefile

# converting data
setwd("c:/R/Rdata")
library(maptools)
library(sp)
library(spatstat)
drumlins <- readShapePoints("drumlins.shp")
class(drumlins)
plot(drumlins)
```



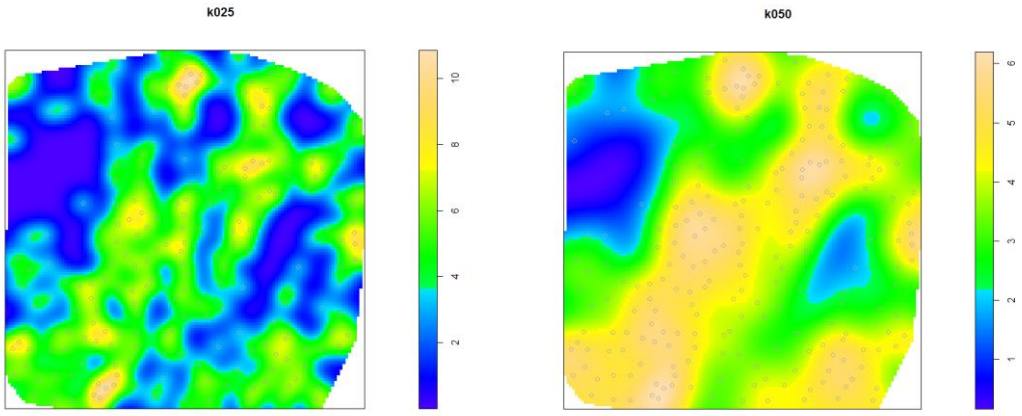
```
drumlins_SP <- as(drumlins,"SpatialPoints")
drumlins_ppp <- as(drumlins_SP,"ppp")
class(drumlins_ppp)
plot(drumlins_ppp)
```



```
plot(density(drumlins_ppp))
plot(drumlins_ppp,add=TRUE)
```




```
# specification of observation window
# bounding box
bb <- bounding.box(drumlins_ppp)
bb
W <- as(bb,"owin")
class(W)
plot(W)

# alternatives for bounding box : convexhull, ripras
ch <- convexhull.xy(drumlins_ppp)
rr <- ripras(drumlins_ppp)

# add observation window to point pattern
drumlins_rr <- ppp(drumlins_ppp$x,drumlins_ppp$y,window=rr)


# density estimates
k025 <- (density(drumlins_rr,0.25))
plot(k025)
plot(drumlins_rr,add=TRUE,col="darkgray")
SG <- as(k025,"SpatialGridDataFrame")
k050 <- (density(drumlins_rr,0.50))
plot(k050)
plot(drumlins_rr,add=TRUE,col="darkgray")
```



Example 2 (crime data)
source data : spatialpolygon shapefile for window and csv-file for points

```
setwd("c:/R/Rdata")
library(maptools)
library(sp)
library(spatstat)
S <- readShapePoly("city_limits_km.shp")
plot(S)
```

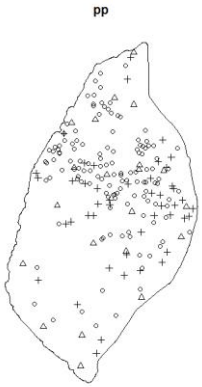
```
SP <- as(S,"SpatialPolygons")
W <- as(SP,"owin")
plot(W)
```

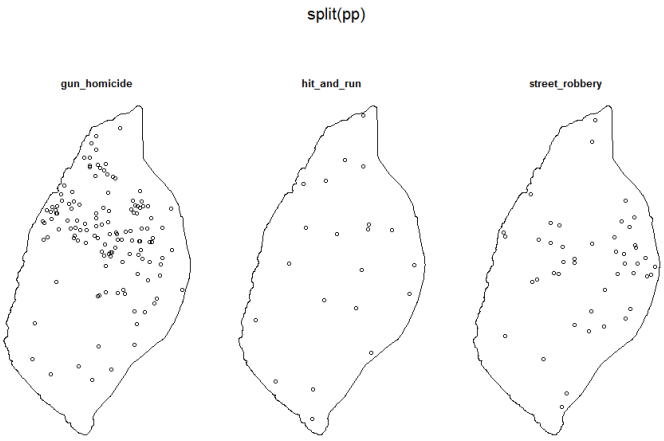

```
xy <- read.table("StLouisCrime1982.txt",header=T,sep="\t")
str(xy)
head(xy)
tail(xy)
```

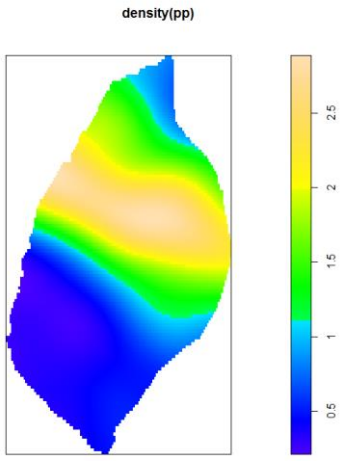
```
> str(xy)
'data.frame':  209 obs. of  8 variables:
 $ ID   : int  764191 764200 764201 764075 764192 764195 764205 764193
764194 764189 ...
 $ X    : num  277 277 277 277 276 ...
 $ Y    : num  310 312 312 315 312 ...
 $ CRIME: Factor w/ 3 levels "gun_homicide",..: 1 1 1 1 1 1 1 1 1 1 ...
 $ YEAR : int  82 82 82 82 82 82 82 82 82 82 ...
 $ MONTH: int  7 9 12 7 1 8 11 3 7 5 ...
 $ DAY  : int  4 19 16 31 12 12 28 26 21 4 ...
 $ HR24 : int  21 12 20 8 2 18 17 18 24 18 ...
```

```
> head(xy)
      ID       X       Y         CRIME YEAR MONTH DAY HR24
1 764191 277.490 309.585 gun_homicide   82     7   4   21
2 764200 276.785 312.246 gun_homicide   82     9  19   12
3 764201 276.785 312.246 gun_homicide   82    12  16   20
4 764075 276.715 315.010 gun_homicide   82     7  31    8
5 764192 276.160 311.722 gun_homicide   82     1  12    2
6 764195 276.160 311.722 gun_homicide   82     8  12   18
> tail(xy)
        ID       X       Y         CRIME YEAR MONTH DAY HR24
204 763994 270.450 300.905 hit_and_run   82     5   4   18
205 764010 270.035 313.758 hit_and_run   82    10  25   19
206 764040 269.862 316.677 hit_and_run   82     6  21   18
207 764113 268.935 311.325 hit_and_run   82     8  31   20
208 763995 268.030 303.453 hit_and_run   82     5   3   14
209 763999 266.705 307.546 hit_and_run   82     9  25    4
```

```
attach(xy)
pp <- ppp(X,Y,window=W,marks=CRIME)
summary(pp)
plot(pp)
plot(split(pp))
plot(density(pp))
```

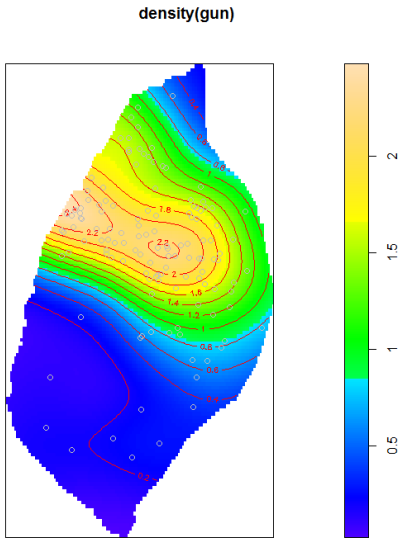


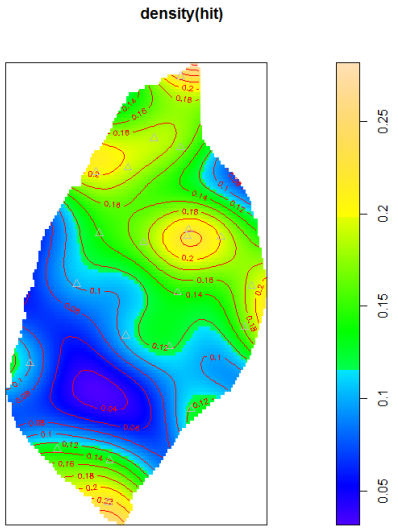


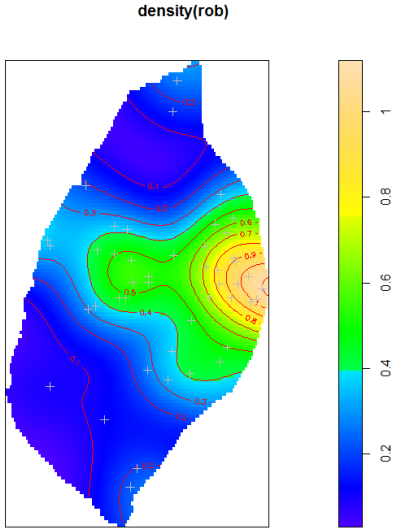



```
gun <- pp[CRIME=="gun_homicide"]
hit <- pp[CRIME=="hit_and_run"]
rob <- pp[CRIME=="street_robbery"]
```

```
plot(density(gun))
contour(density(gun),col="red",add=T)
plot(gun,col="gray",add=T)
plot(density(hit))
contour(density(hit),col="red",add=T)
plot(hit,col="gray",add=T)
plot(density(rob))
contour(density(rob),col="red",add=T)
plot(rob,col="gray",add=T)
```



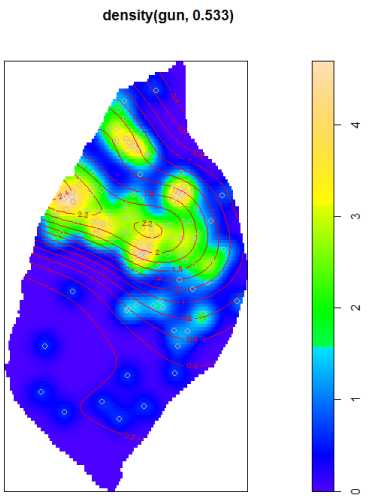




# R provides a function that will suggest on optimal bandwidth to use
r <- bw.diggle(gun)
r

```
sigma
0.5334841
```

plot(density(gun,0.533))
contour(density(gun),col="red",add=T)
plot(gun,col="gray",add=T)

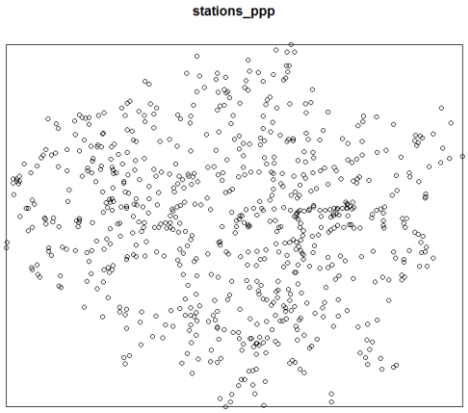


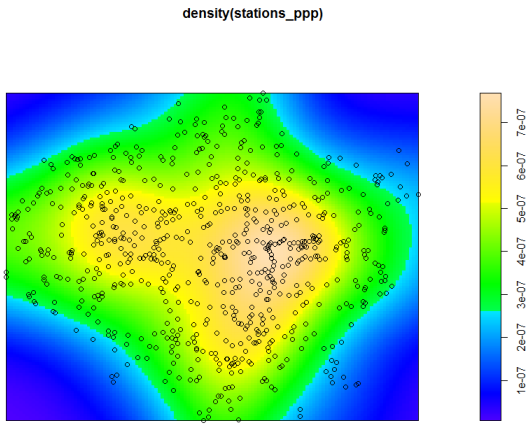
Example 3 (London transport points)
source data : R workspace (2 shapefiles : SpatialPolygonsDataFrame & SpatialPpointsDataFrame)

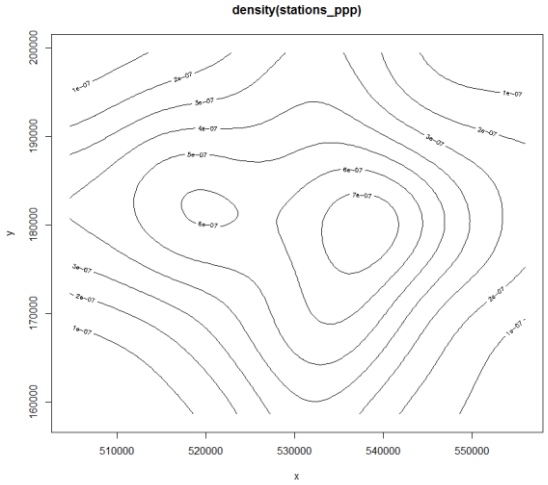
the aim of this exercise is to demonstrate how clusters can be identified in spatial points
these clusters are then used as the basis of aggregation to reduce the total number of points

```
library(maptools)
library(sp)
library(spatstat)
setwd("c:/R/Rdata")
load("lnd.Rdata")
class(lnd)
plot(lnd)
load("stations.Rdata")
class(stations)
plot(stations)
```

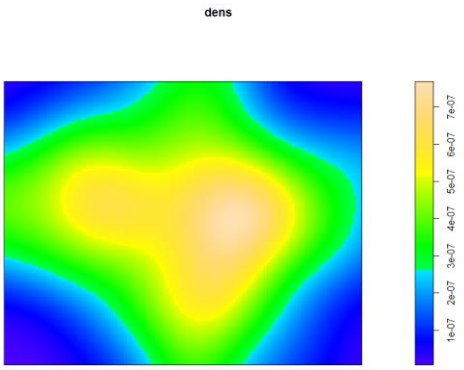
```
stations_SP <- as(stations,"SpatialPoints")
stations_ppp <- as(stations_SP,"ppp")
class(stations_ppp)
plot(stations_ppp)
```



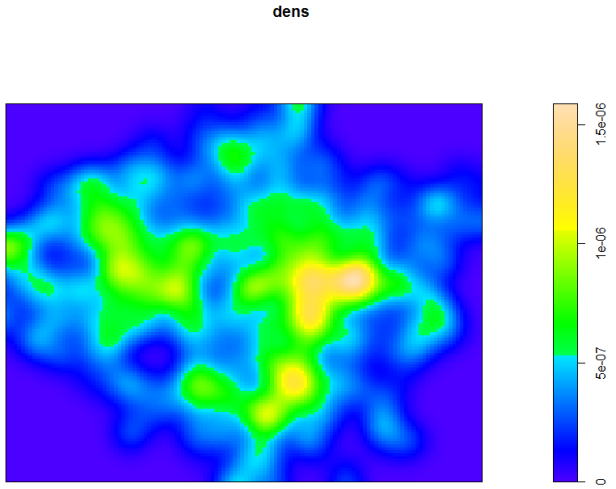




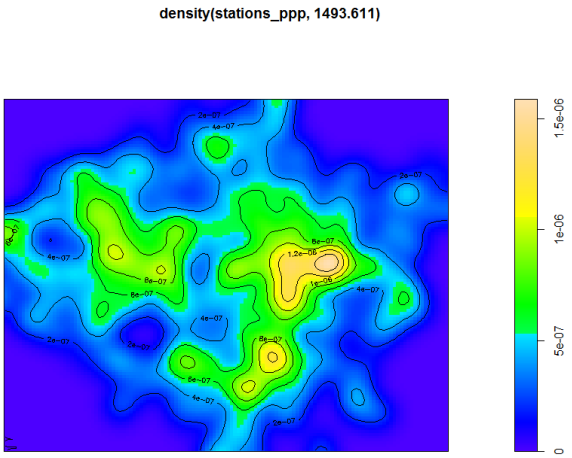

```
dens <- density(stations_ppp)
class(dens)
plot(dens)
```



```
r <- bw.diggle(stations_ppp)
r

dens <- density(stations_ppp,1493.611)
class(dens)
plot(dens)
```

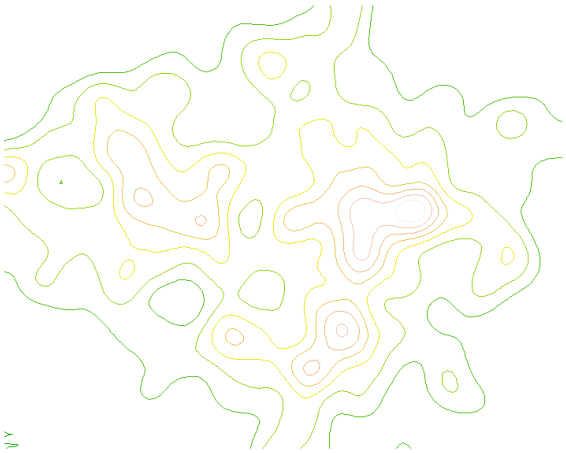



```
plot(density(stations_ppp,1493.611))
contour(density(stations_ppp,1493.611),add=T)
```

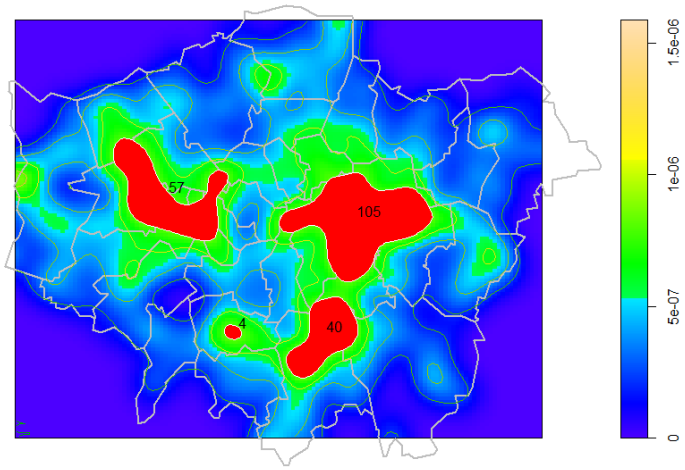



```
# the density plot illustrates that there are some areas of relatively high density
# this concentration is also illustrated by the contour lines
# having identified the "islands" of hot dot density, the next stage is to save them into polygons
```

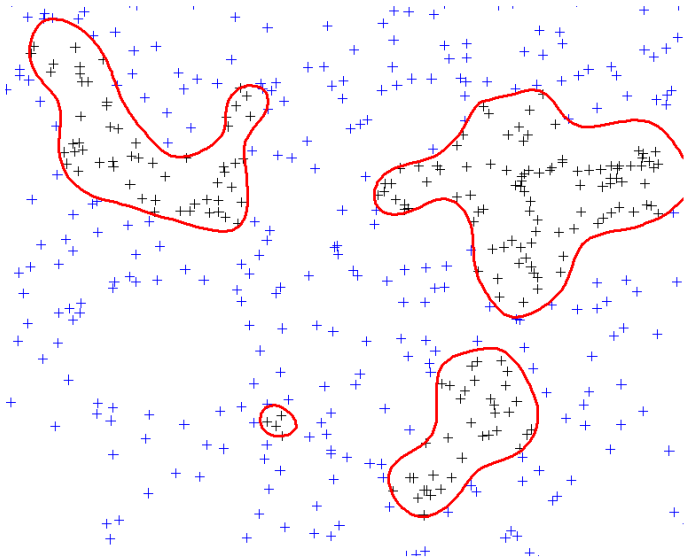
```
# convert to spatial grid
Dsg <- as(dens,"SpatialGridDataFrame")
class(Dsg)
# convert again to an image
Dim <- as.image.SpatialGridDataFrame(Dsg)
Dcl <- contourLines(Dim,nlevels=9)
# convert to SpatialLinesDataFrame
SLDF <- ContourLines2SLDF(Dcl,CRS(proj4string(lnd)))
plot(SLDF,col = terrain.colors(8))
```



```
library(rgeos)
Polyclust <- gPolygonize(SLDF[5, ])
gas <- gArea(Polyclust,byid=T)/10000
Polyclust <- SpatialPolygonsDataFrame(Polyclust,data=data.frame(gas),match.ID=F)
plot(Polyclust)
cag <- aggregate(stations,by=Polyclust,FUN=length)
plot(dens,main=" ")
plot(lnd,border="grey",lwd=2,add=T)
plot(SLDF,col=terrain.colors(8),add=T)
plot(cag,col="red",border="white",add=T)
graphics::text(coordinates(cag) + 1000, labels = cag$CODE)
```




```
# points inside and outside the clusters
sIn <- stations [cag, ]
plot(sIn)
sOut <- stations[!row.names(stations) %in% row.names(sIn), ]
plot(sOut,col="blue",add=T)
plot(cag,border="red",lwd=3,add=T)
```

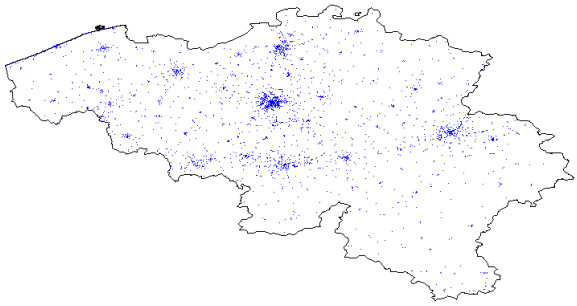


```
nrow(sIn)/nrow(stations)
> nrow(sIn)/nrow(stations)
[1] 0.2818057
```

```
# Example 4
# source data : spatialpolygon shapefile for window and csv-file for points

setwd("c:/R/Rdata")
# read shapefile Belgium
library(maptools)
Belgie <- readShapePoly("Bel_adm0.shp")
plot(Belgie)
```

```
# read pointdata
pos <- read.csv("poslatlon.csv",header=TRUE,sep=";")
str(pos)
head(pos)
points(pos$lon,pos$lat,pch=".",col="blue")
```

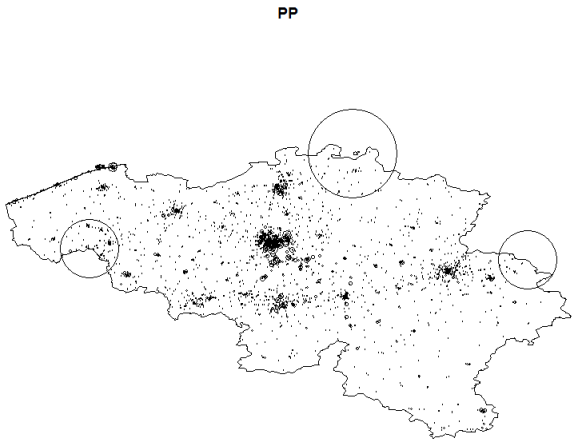
```
> str(pos)
'data.frame':   3454 obs. of  7 variables:
 $ verknr    : Factor w/ 3454 levels "001N","001V",..: 1 2 3 4 5 6 7 8 9 10
...
 $ outlettype: Factor w/ 13 levels "Atypical press points",..: 1 12 13 13
13 12 13 12 13 13 ...
 $ sales     : int  11 1 3 0 3 6 2 4 3 15 ...
 $ unsolds   : int  37 71 61 93 57 54 0 25 0 47 ...
 $ lat       : num  50.5 50.9 50.5 51.2 50.9 ...
 $ lon       : num  5.1 4.28 4.19 4.14 4.39 ...
 $ case      : int  0 0 0 0 0 0 0 0 0 0 ...
> head(pos)
  verknr            outlettype sales unsolds      lat      lon case
1   001N Atypical press points    11      37 50.49119 5.096621    0
2   001V       Petrol stations     1      71 50.87947 4.279605    0
3   002M         Press outlets     3      61 50.47002 4.188878    0
4   002S         Press outlets     0      93 51.16429 4.139056    0
5   002V         Press outlets     3      57 50.87179 4.393806    0
6   002W       Petrol stations     6      54 50.70069 4.669694    0
> points(pos$lon,pos$lat,pch=".",col="blue")
```



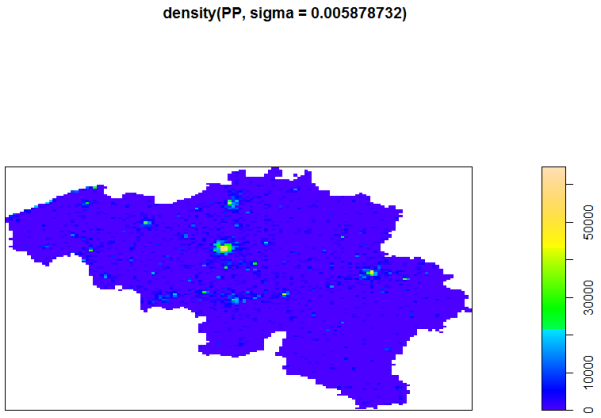
```
# define observation window based on shapefile
library(spatstat)
library(sp)
SP <- as(Belgie,"SpatialPolygons")
W <- as(SP,"owin")
plot(W)
```

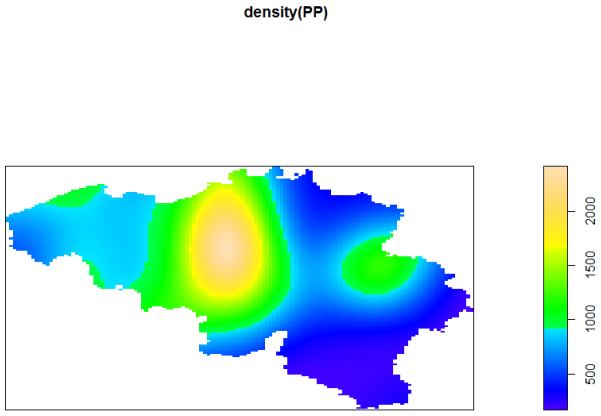
```
# define point pattern with marks as a continuous variable
PP <- ppp(pos$lon,pos$lat,window=W,marks=pos$sales)
plot(PP)
class(PP)
summary(PP)
```

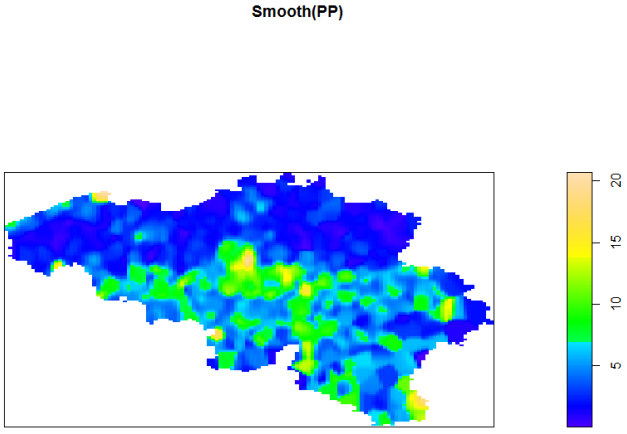
```
> class(PP)
[1] "ppp"
> summary(PP)
Marked planar point pattern: 3451 points
Average intensity 885 points per square unit

*Pattern contains duplicated points*

Coordinates are given to 6 decimal places

marks are  numeric,  of type 'integer'
Summary:
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
  0.000   2.000   4.000   5.922   7.000  75.000

Window: polygonal boundary
3 separate polygons (no holes)
           vertices        area relative.area
polygon 1        15 0.000027781      7.12e-06
polygon 2        22 0.000590017      1.51e-04
polygon 3      4685 3.899550000      1.00e+00
enclosing rectangle: [2.555356, 6.40834] x [49.49722, 51.50382] units
Window area =  3.90017 square units

*** 3 illegal points stored in attr(,"rejects") ***
```



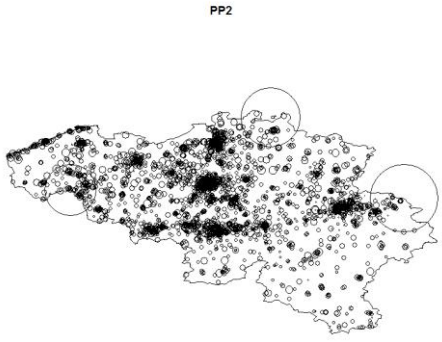
```
r <- bw.diggle(PP)
r

plot(density(PP,sigma=0.005878732))
plot(density(PP))
plot(Smooth(PP))
```

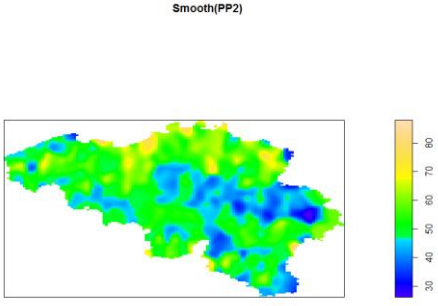







```
PP2 <- ppp(pos$lon,pos$lat,window=W,marks=pos$unsolds)
plot(PP2)
plot(Smooth(PP2))
```

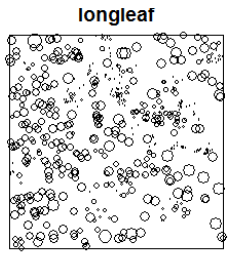


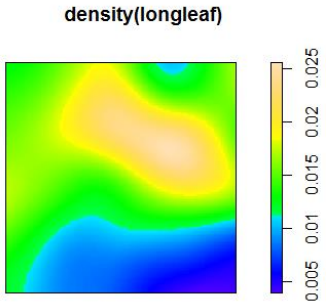


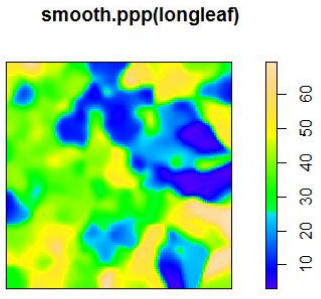
density.ppp computes a kernel smoothed intensity function from a point pattern.
smooth.ppp computes a kernel-smoothed average of the mark values of the point pattern.

For example, with the longleaf pattern of trees marked by their diameter at breast heigt, plot(smooth.ppp(longleaf)) will show you a map of the spatially varying average diameter of trees.

```
library(spatstat)
data(longleaf)
plot(longleaf)
plot(density(longleaf))
plot(smooth.ppp(longleaf))
```





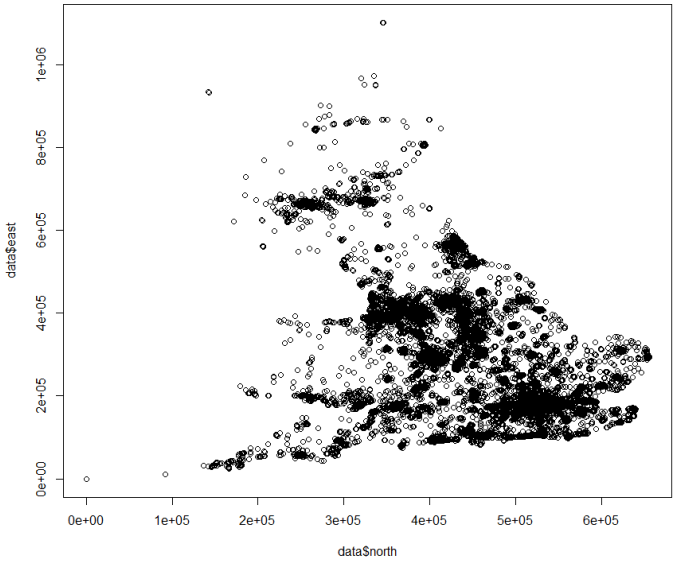


smooth.ppp does not compute the desnsity of weighted points. That is computed by density.ppp with the argument 'weights' (see example 9).

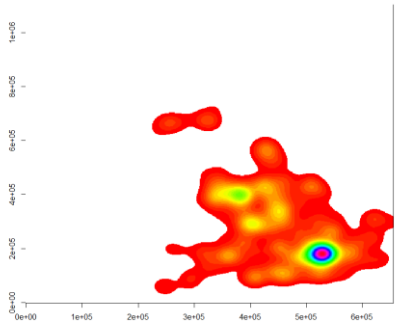
```
# Example 5
# source data : csv-file (with north/east coordinates)

setwd("c:/R/Rdata")
data <- scan("2005.csv",skip=1,what=list(tear=0,north=0,east=0),sep=",",quiet=T)
str(data)
```

```
> str(data)
List of 3
 $ tear : num [1:16856] 2005 2005 2005 2005 2005 ...
 $ north: num [1:16856] 525000 525410 527010 526670 526640 ...
 $ east : num [1:16856] 180660 180490 179030 178190 177580 ...
```

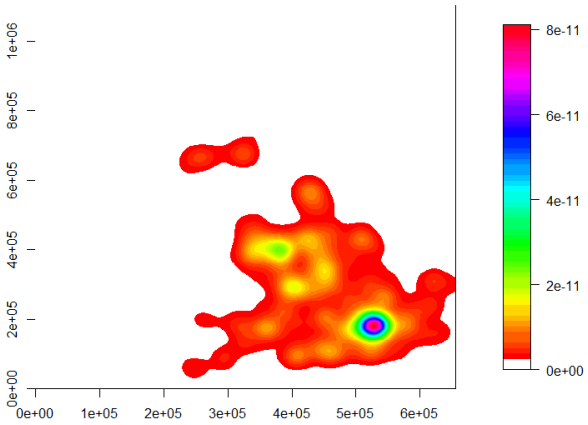
```
plot(data$north,data$east)
```



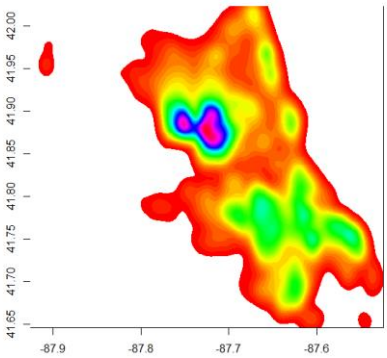

```
library(MASS)
# create a density plot using kde2d-function
# kernel is a list containing 3 items : x and y representing the grid and z a 500 * 500 matrix
# containing the kernel density for each cell of the grid
kernel <- kde2d(data$north,data$east,n=500)
image(kernel,col=c(0,rainbow(50)))
```



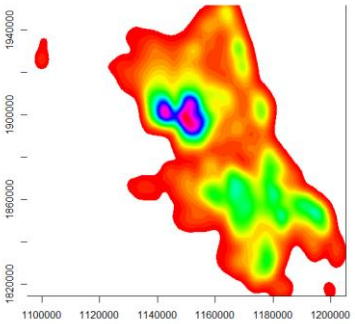
```
# to add a colour legend to the z-plot, use package "fields"
library(fields)
image.plot(kernel,col=c(0,rainbow(50)))
```



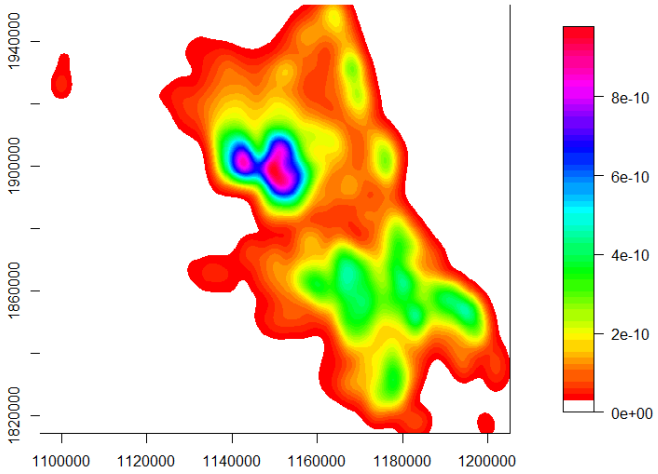

```
# applying the same logic to crime data Chicago area, 2013
setwd("c:/R/Rdata/chicago")
chicago <- read.csv("chicagocrimes_2013.csv",header=T,sep=",")
data <- subset(chicago,Primary.Type=="ARSON" | Primary.Type=="BURGLARY" |
                       Primary.Type=="ASSAULT" | Primary.Type=="ROBBERY" |
                       Primary.Type=="NARCOTICS" | Primary.Type=="HOMICIDE" |
                       Primary.Type=="SEX OFFENSE",
                       select=c(Longitude,Latitude,Primary.Type))
data <- na.omit(data)
library(MASS)
kernel <- kde2d(data$Longitude,data$Latitude,n=500)
image(kernel,col=c(0,rainbow(50)))
```



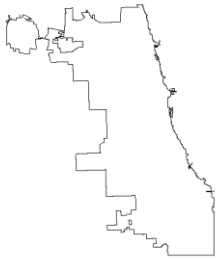
```
data <- subset(chicago,Primary.Type=="ARSON" | Primary.Type=="BURGLARY" |
                       Primary.Type=="ASSAULT" | Primary.Type=="ROBBERY" |
                       Primary.Type=="NARCOTICS" | Primary.Type=="HOMICIDE" |
                       Primary.Type=="SEX OFFENSE",
                       select=c(X.Coordinate,Y.Coordinate,Primary.Type))
data <- na.omit(data)
str(data)
plot(data$X.Coordinate,data$Y.Coordinate)
library(MASS)
kernel <- kde2d(data$X.Coordinate,data$Y.Coordinate,n=500)
image(kernel,col=c(0,rainbow(50)))
```



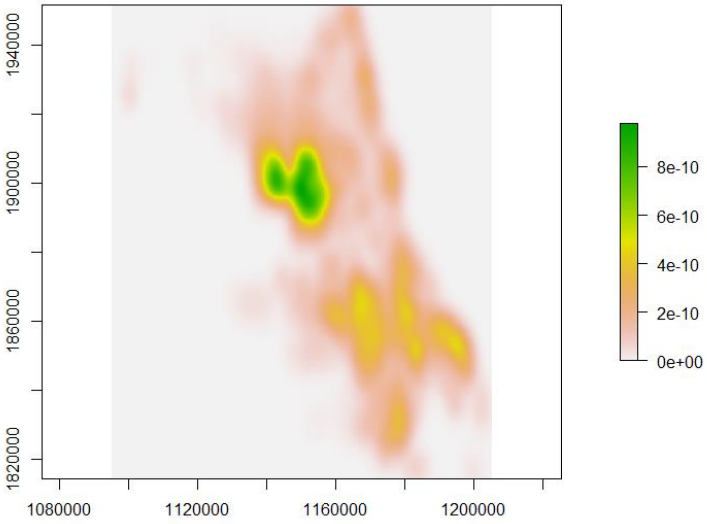

```
# to add a colour legend to the z-plot, use package "fields"
library(fields)
image <- image.plot(kernel,col=c(0,rainbow(50)))
```



```
# add shapefile boundary to the plots
# read shapefile, convert kernel density estimates to raster and finally clip raster
# read shapefile Chicago
library(maptools)
ch <- readShapePoly("City_Boundary.shp")
plot(ch)
```

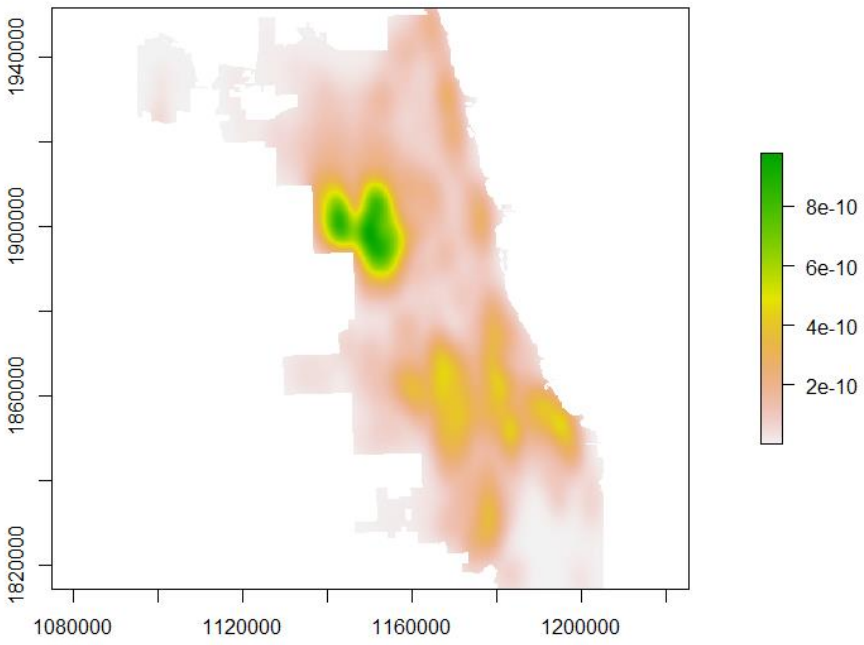


```
library(raster)
r <- raster(kernel)
plot(r)
projection(r) <- CRS("+init=epsg:4326")
writeRaster(r,"chicagocrime.tiff","GTiff",overwrite=TRUE)
```

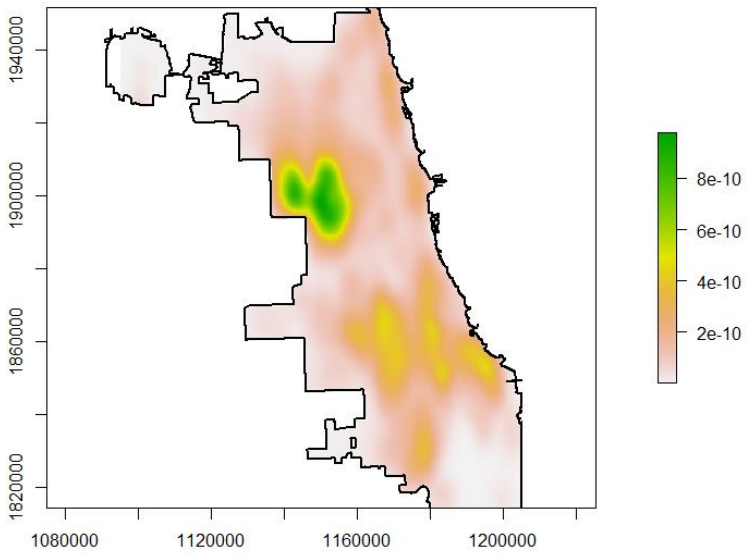


```
> writeRaster(r,"chicagocrime.tiff","GTiff",overwrite=TRUE)
rgdal: version: 0.8-11, (SVN revision 479M)
Geospatial Data Abstraction Library extensions to R successfully loaded
Loaded GDAL runtime: GDAL 1.9.2, released 2012/10/08
Path to GDAL shared files: C:/Users/Studiebureau/Documents/R/win-
library/3.0/rgdal/gdal
GDAL does not use iconv for recoding strings.
Loaded PROJ.4 runtime: Rel. 4.7.1, 23 September 2009, [PJ_VERSION: 470]
Path to PROJ.4 shared files: C:/Users/Studiebureau/Documents/R/win-
library/3.0/rgdal/proj
class       : RasterLayer
dimensions  : 500, 500, 250000  (nrow, ncol, ncell)
resolution  : 220.3547, 274.8116  (x, y)
extent      : 1095010, 1205187, 1814333, 1951738  (xmin, xmax, ymin, ymax)
coord. ref. : +proj=longlat +datum=WGS84 +no_defs +ellps=WGS84
+towgs84=0,0,0
data source : c:\R\Rdata\chicago\chicagocrime.tif
names       : chicagocrime
values      : 4.351175e-135, 9.774871e-10  (min, max)
```

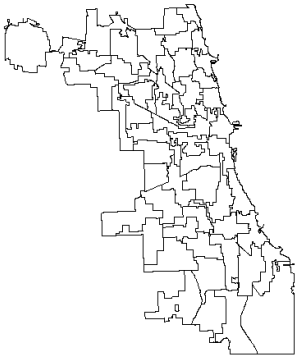
```
r2 <- crop(r,extent(ch))
r3 <- mask(r2,ch)
plot(r3)
```



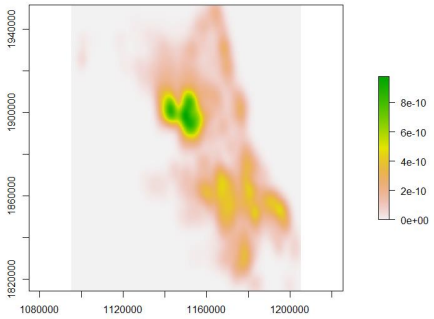
```
plot(ch, add=TRUE, lwd=2)
```



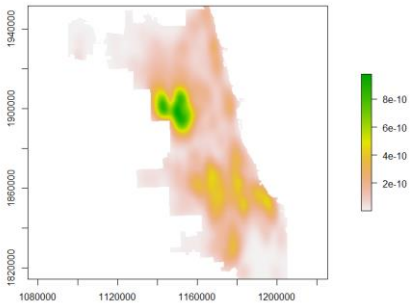

```
# clipping the raster file with a shapefile containing multiple polygons
ch2 <- readShapePoly("wards.shp")
plot(ch2)
```



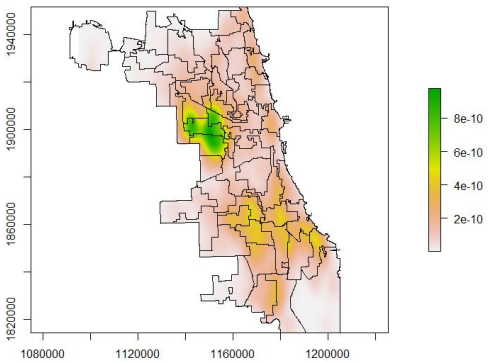
plot(r)



rr <- mask(r,ch2)
plot(rr)



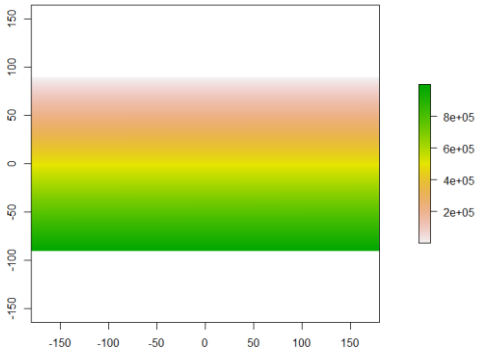
plot(ch2,add=TRUE)



Example 6 : clipping a raster (1)

Example SpatialPolygonsDataFrame
data(wrld_simpl)
SPDF <- subset(wrld_simpl, NAME=="Brazil")
plot(SPDF)

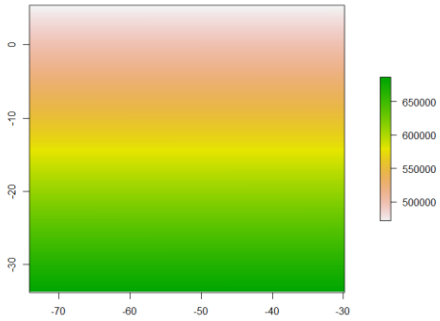
Example RasterLayer
r <- raster(nrow=1e3, ncol=1e3)
r[] <- 1:length(r)
plot(r)



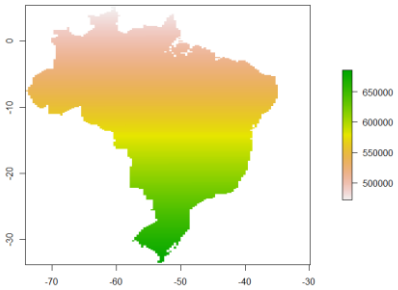
crop and mask
r2 <- crop(r, extent(SPDF))
r3 <- mask(r2, SPDF)

```
> r3 <- mask(r2, SPDF)
Found 1 region(s) and 62 polygon(s)
```

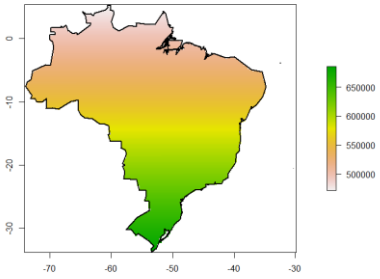
plot(r2)



plot(r3)



plot(SPDF, add=TRUE, lwd=2)



Example 7 : clipping a raster (2)

```
setwd("c:/R/Rdata")

library(rgdal)
library(raster)

# shapefile US = "USA_adm1.shp"
# get this shapefile from www.gadm.org
us <- getData("GADM",country="USA",level=1)
summary(us)
```

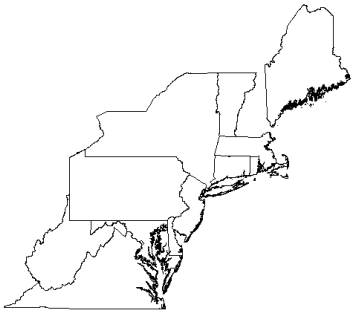
```
> summary(us)
Object of class SpatialPolygonsDataFrame
Coordinates:
           min        max
r1 -179.15056 179.77341
r2   18.90986  71.39069
Is projected: FALSE
proj4string :
[+proj=longlat +datum=WGS84 +ellps=WGS84 +towgs84=0,0,0]
Data attributes:
     ID_0      ISO               NAME_0        ID_1              NAME_1       VARNAME_1  NL_NAME_1
HASC_1     CC_1               TYPE_1
 Min.   :234   USA:51   United States:51   Min.   :3191   Alabama    : 1   AK|Alaska: 1   NA's:51   US.AK  :
1   NA's:51   Federal District: 1
 1st Qu.:234                              1st Qu.:3204   Alaska     : 1   AL|Ala.  : 1              US.AL  :
1            State           :50
 Median :234                              Median :3216   Arizona    : 1   AR|Ark.  : 1              US.AR  :
1
 Mean   :234                              Mean   :3216   Arkansas   : 1   AZ|Ariz. : 1              US.AZ  :
1
 3rd Qu.:234                              3rd Qu.:3228   California: 1   CA|Calif.: 1              US.CA  :
1
 Max.   :234                              Max.   :3241   Colorado   : 1   CO|Colo. : 1              US.CO  :
1
                                                         (Other)    :45   (Other)  :45
(Other):45
           ENGTYPE_1     VALIDFR_1    VALIDTO_1  REMARKS_1   Shape_Leng         Shape_Area
 Federal District: 1   17760704: 8   Present:51   NA's:51   Min.   :  0.6128   Min.   :  0.01725
 State           :50   18640526: 3                          1st Qu.: 21.4184   1st Qu.:  9.81765
                       17710304: 2                          Median : 23.6599   Median : 14.65424
                       18170815: 2                          Mean   : 47.5481   Mean   : 21.94257
                       18200316: 2                          3rd Qu.: 33.5381   3rd Qu.: 23.71332
                       18500909: 2                          Max.   :802.6560   Max.   :281.24187
                       (Other) :32
```

```
plot(us)
```

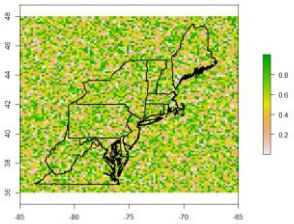
str(us@data)

```
> str(us@data)
'data.frame':   51 obs. of  16 variables:
 $ ID_0      : int  234 234 234 234 234 234 234 234 234 234 ...
 $ ISO       : Factor w/ 1 level "USA": 1 1 1 1 1 1 1 1 1 1 ...
 $ NAME_0    : Factor w/ 1 level "United States": 1 1 1 1 1 1 1 1 1 1 ...
 $ ID_1      : int  3191 3192 3193 3194 3195 3196 3197 3198 3199 3200 ...
 $ NAME_1    : Factor w/ 51 levels "Alabama","Alaska",..: 1 2 3 4 5 6 7 8 9 10 ...
 $ VARNAME_1 : Factor w/ 51 levels "AK|Alaska","AL|Ala.",..: 2 1 4 3 5 6 10 12 11 13 ...
 $ NL_NAME_1 : Factor w/ 0 levels: NA NA NA NA NA NA NA NA NA NA ...
 $ HASC_1    : Factor w/ 51 levels "US.AK","US.AL",..: 2 1 4 3 5 6 7 9 8 10 ...
 $ CC_1      : Factor w/ 0 levels: NA NA NA NA NA NA NA NA NA NA ...
 $ TYPE_1    : Factor w/ 2 levels "Federal District",..: 2 2 2 2 2 2 2 2 1 2 ...
 $ ENGTYPE_1 : Factor w/ 2 levels "Federal District",..: 2 2 2 2 2 2 2 2 1 2 ...
 $ VALIDFR_1 : Factor w/ 35 levels "17710304","17760704",..: 10 31 30 15 20 24 2 2 18 14 ...
 $ VALIDTO_1 : Factor w/ 1 level "Present": 1 1 1 1 1 1 1 1 1 1 ...
 $ REMARKS_1 : Factor w/ 0 levels: NA NA NA NA NA NA NA NA NA NA ...
 $ Shape_Leng: num  21.5 802.7 23.8 21.6 56.4 ...
 $ Shape_Area: num  12.9 281.2 28.9 13.6 41.6 ...
```

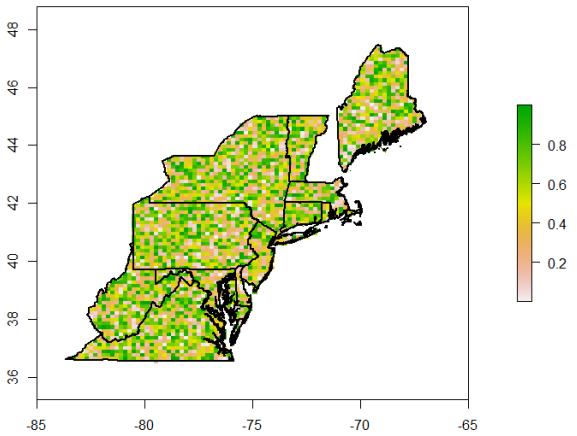
```
# subset US shapefile to desired states
selectstates <- c("Maine","Vermont","Massachusetts","New Hapshire","Connecticut","Rhode Island",
        "New York","Pennsylvania","New Jersey","Maryland","Delaware","Virginia","West Virginia")
us.sub <- us[as.character(us@data$NAME_1) %in% selectstates, ]
plot(us.sub)
```



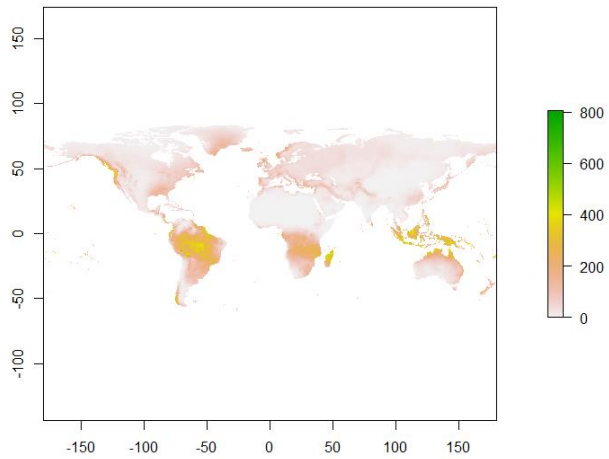
```
# create a random raster over the space
r <- raster(xmn=-85,xmx=-65,ymn=36,ymx=48,nrow=100,ncol=100)
r[] <- runif(100*100)
plot(r)
plot(us.sub,lwd=2,add=T)
```



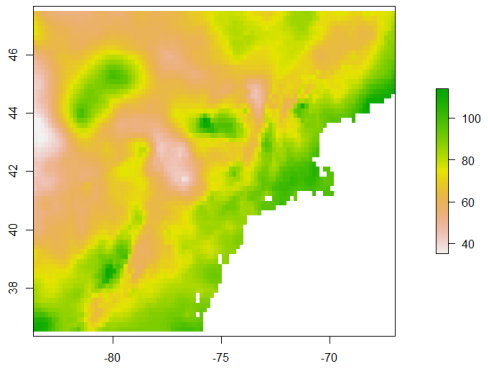
```
# use the mask function
rr <- mask(r,us.sub)
plot(rr)
plot(us.sub,lwd=2,add=T)
```



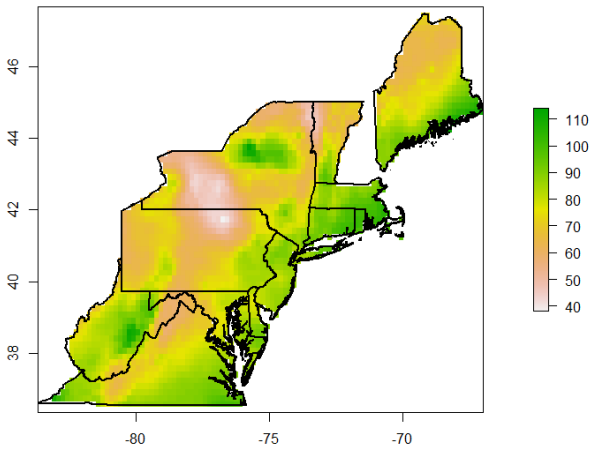

```
# use precipitation rasterfile
precipitation <- raster("prec1.bil")
plot(precipitation)
```



```
# crop precipitation data by extent of states subset
precipitation.sub <- crop(precipitation,extent(us.sub))
plot(precipitation.sub)
```




```
# as a final step we need to identify those pixels of the precipitation raster file
# that lie within the borders of the states subset file
precipitation.sub <- mask(precipitation.sub,us.sub)
plot(precipitation.sub)
plot(us.sub,lwd=2,add=T)
```

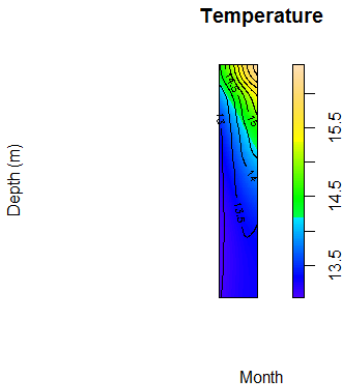


Example 8 : smooth.ppp

```
df = data.frame(depth = c(-5, -10, -15, -20, -25, -30, -35,
                          -5, -10, -15, -20, -25, -30, -35,
                          -5, -10, -15, -20, -25, -30, -35),
                date = as.POSIXlt(c("2014-02-02", "2014-02-02", "2014-02-02", "2014-02-02", "2014-02-02",
                                    "2014-02-02", "2014-02-02", "2014-04-14", "2014-04-14", "2014-04-14",
                                    "2014-04-14", "2014-04-14", "2014-04-14", "2014-04-14", "2014-07-21",
                                    "2014-07-21","2014-07-21","2014-07-21","2014-07-21","2014-07-21","2014-07-21")),
                temperature = c(11.9071,11.9657,11.9751,11.9813,
                                11.9972,12.0255,12.1483,17.0442,
                                14.3784,14.2104,14.2206,14.1834,
                                14.1979,14.2189,18.4762,16.3302,
                                15.1438,14.0497,13.346,13.0996,13.0504))
df$month <- as.numeric(format(df$date, "%m"))
str(df)
head(df)
```

```
> str(df)
'data.frame':   21 obs. of  4 variables:
 $ depth      : num  -5 -10 -15 -20 -25 -30 -35 -5 -10 -15 ...
 $ date       : POSIXct, format: "2014-02-02" "2014-02-02" "2014-02-02"
"2014-02-02" ...
 $ temperature: num  11.9 12 12 12 12 ...
 $ month      : num  2 2 2 2 2 2 2 4 4 4 ...
> head(df)
  depth       date temperature month
1    -5 2014-02-02     11.9071     2
2   -10 2014-02-02     11.9657     2
3   -15 2014-02-02     11.9751     2
4   -20 2014-02-02     11.9813     2
5   -25 2014-02-02     11.9972     2
6   -30 2014-02-02     12.0255     2
```

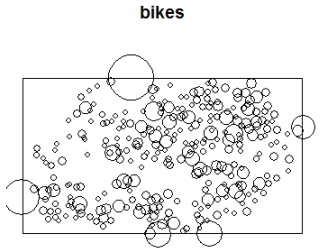
```
library(spatstat)
C <- ppp(df$month, df$depth, c(2,7), c(-35, -5))
marks(C) <- df["temperature"]
C.smooth <- Smooth.ppp(C, sigma = 2)
plot(Smooth(C), col = topo.colors(128),
   main="Temperature", ylab="Depth (m)",
   ylim=TRUE,xlab="Month")
contour(C.smooth, add = TRUE)
```

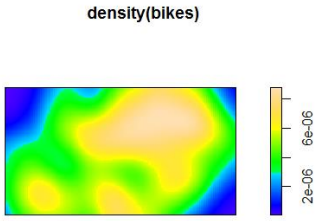


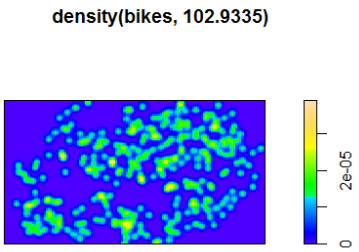
```
# Example 9
# kernel  density estimation map of point pattern with package spatstat
# data : polygon shapefile & csv-pointfile

setwd("c:/R/Rdata/shapefiles")
library(maptools)
library(sp)
library(spatstat)
city_shp <- readShapePoly("lond_city.shp")
city_win <- as(as(city_shp,"SpatialPolygons"),"owin")
plot(city_win)
bikedata <- read.csv("London_cycle_hire_locs.csv",header=TRUE,sep=",")
str(bikedata)
head(bikedata)
summary(bikedata$X)
summary(bikedata$Y)
bikes <- ppp(bikedata$X,bikedata$Y,marks=bikedata$Capacity,window=city_win)
bikes <- ppp(bikedata$X,bikedata$Y,c(524400,534700),c(177900,183600),marks=bikedata$Capacity)
points(bikedata$X,bikedata$Y)
```

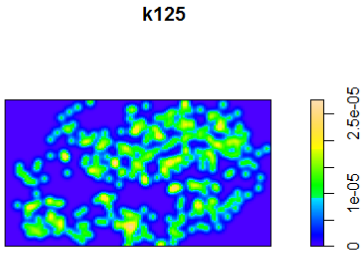
```
> str(bikedata)
'data.frame':  292 obs. of  5 variables:
 $ Name    : Factor w/ 292 levels "Abbey Orchard Street",..: 144 135 51 261
282 199 202 2 183 260 ...
 $ Village : Factor w/ 64 levels "Aldgate","Angel",..: 37 26 36 36 14 36 26
26 36 14 ...
 $ X       : int  524384 524844 524897 524940 525174 525179 525207 525236
525262 525329 ...
 $ Y       : int  179210 179509 180779 181022 178737 180668 179392 179146
180478 178421 ...
 $ Capacity: int  25 24 17 21 24 16 37 17 16 18 ...
> head(bikedata)
                       Name      Village      X      Y Capacity
1 Kensington Olympia Station      Olympia 524384 179210       25
2            Ilchester Place   Kensington 524844 179509       24
3            Chepstow Villas Notting Hill 524897 180779       17
4          Turquoise Island Notting Hill 524940 181022       21
5         West Cromwell Road Earl's Court 525174 178737       24
6           Pembridge Villas Notting Hill 525179 180668       16
> summary(bikedata$X)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 524400  528000  529900  529800  531900  534700
> summary(bikedata$Y)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 177900  179400  180900  180800  182000  183600
> bikes <-
ppp(bikedata$X,bikedata$Y,marks=bikedata$Capacity,window=city_win)
Warning message:
In ppp(bikedata$X, bikedata$Y, marks = bikedata$Capacity, window =
city_win) :
  270 points were rejected as lying outside the specified window
> bikes <-
ppp(bikedata$X,bikedata$Y,c(524400,534700),c(177900,183600),marks=bikedata$
Capacity)
Warning message:
In ppp(bikedata$X, bikedata$Y, c(524400, 534700), c(177900, 183600),  :
  5 points were rejected as lying outside the specified window
```

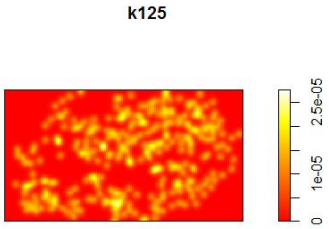
```
plot(bikes)
plot(density(bikes))
r <- bw.diggle(bikes)
r
plot(density(bikes,102.9335))
k125 <- density.ppp(bikes,sigma=125,weights=bikes$Capacity)
plot(k125)
plot(k125,col=heat.colors(256))
plot(Smooth.ppp(bikes))
plot(bikes,add=T)
plot(city_win,lwd=2,add=T)
```

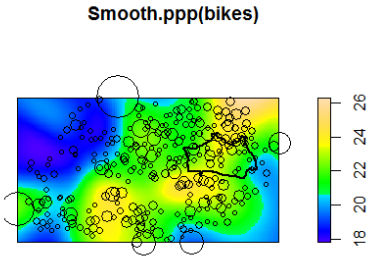




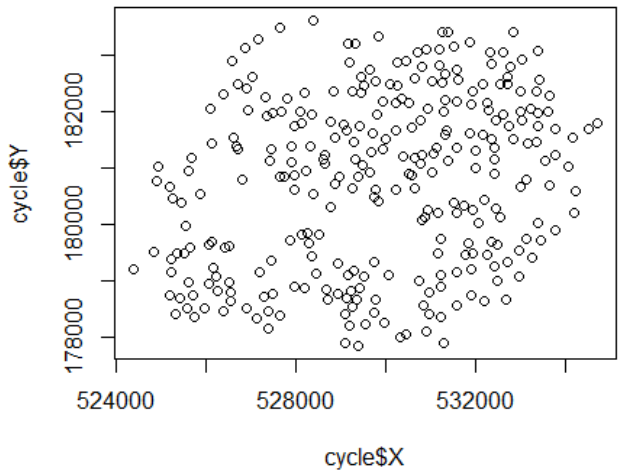






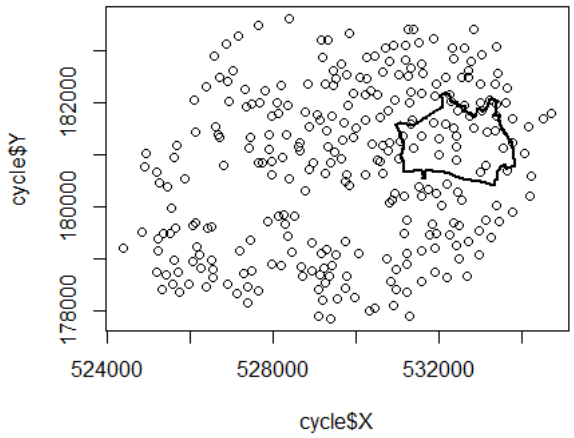


```
# Example 10
# the following example will outline how to create a surface using kernel density estimation (KDE)
# and then clip the surface so that it is constrained within the limits of a polygon
# data : polygon shapefile & csv-pointfile

setwd("c:/R/Rdata/shapefiles")
cycle <- read.csv("London_cycle_hire_locs.csv",header=TRUE,sep=",")
str(cycle)
head(cycle)
plot(cycle$X,cycle$Y)
```

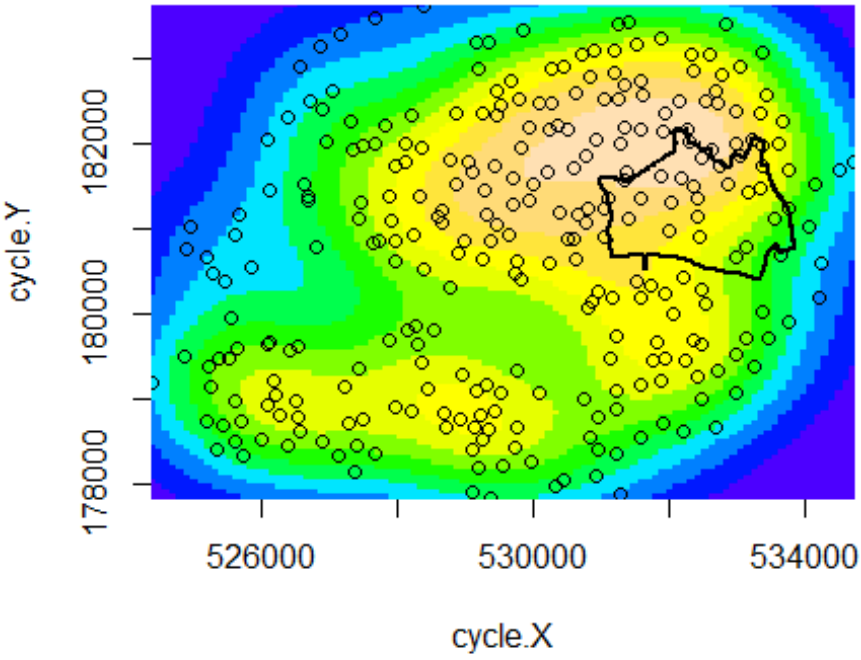



```
library(maptools)
lon_city <- readShapePoly("lond_city.shp")
summary(lon_city)
str(lon_city@data)
plot(cycle$X,cycle$Y)
plot(lon_city,add=TRUE,lwd=2)
```

```
> str(lon_city@data)
'data.frame':  1 obs. of  7 variables:
 $ ons_label: Factor w/ 1 level "00AA": 1
 $ name     : Factor w/ 1 level "City of London": 1
 $ label    : Factor w/ 1 level "02AA": 1
 $ X_max    : num 533843
 $ y_max    : num 182198
 $ X_min    : num 0
 $ y_min    : num 0
 - attr(*, "data_types")= chr  "C" "C" "C" "F" ...
```



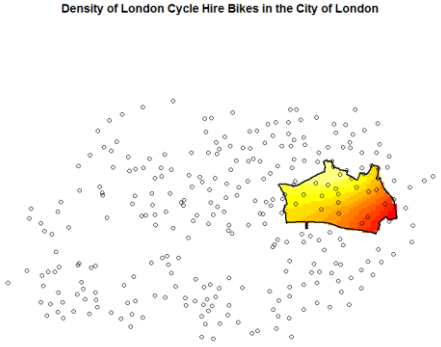

```
# create a kernel density surface based on the locations of the points
# we use the sm.density function in the sm package
library(sm)
cycle_dens <-
sm.density(data.frame(cycle$X,cycle$Y),weights=cycle$Capacity,display="image",ngrid=100)
# add the points and the polygon
points(cycle$X,cycle$Y)
plot(lon_city,add=T,lwd=2)
```



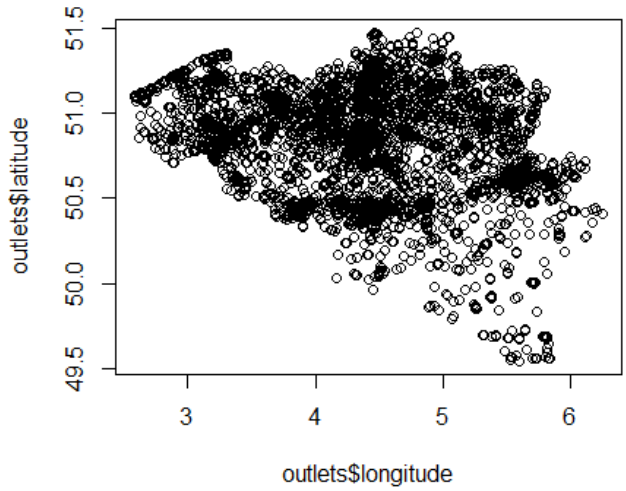
str(cycle_dens)

```
> str(cycle_dens)
List of 10
 $ eval.points: num [1:100, 1:2] 524384 524488 524593 524697 524802 ...
  ..- attr(*, "dimnames")=List of 2
  .. ..$ : NULL
  .. ..$ : chr [1:2] "xgrid" "ygrid"
 $ estimate   : num [1:100, 1:100] 1.79e-09 2.04e-09 2.31e-09 2.58e-09
2.87e-09 ...
 $ h          : Named num [1:2] 962 591
  ..- attr(*, "names")= chr [1:2] "cycle.X" "cycle.Y"
 $ h.weights  : num [1:292] 1 1 1 1 1 1 1 1 1 1 ...
 $ weights    : int [1:292] 25 24 17 21 24 16 37 17 16 18 ...
 $ se         : num [1:100, 1:100] 2.34e-06 2.34e-06 2.34e-06 2.34e-06
2.34e-06 ...
 $ upper      : num [1:100, 1:100] 2.21e-09 2.49e-09 2.78e-09 3.08e-09
3.40e-09 ...
 $ lower      : num [1:100, 1:100] 1.42e-09 1.64e-09 1.88e-09 2.13e-09
2.39e-09 ...
 $ data       :List of 3
  ..$ x    : int [1:292, 1:2] 524384 524844 524897 524940 525174 525179
525207 525236 525262 525329 ...
  .. ..- attr(*, "dimnames")=List of 2
  .. .. ..$ : NULL
  .. .. ..$ : chr [1:2] "cycle.X" "cycle.Y"
  ..$ nbins: num 0
  ..$ freq : int [1:292] 25 24 17 21 24 16 37 17 16 18 ...
 $ call       : language sm.density(x = data.frame(cycle$X, cycle$Y),
weights = cycle$Capacity, display = "image", ngrid = 100)
```

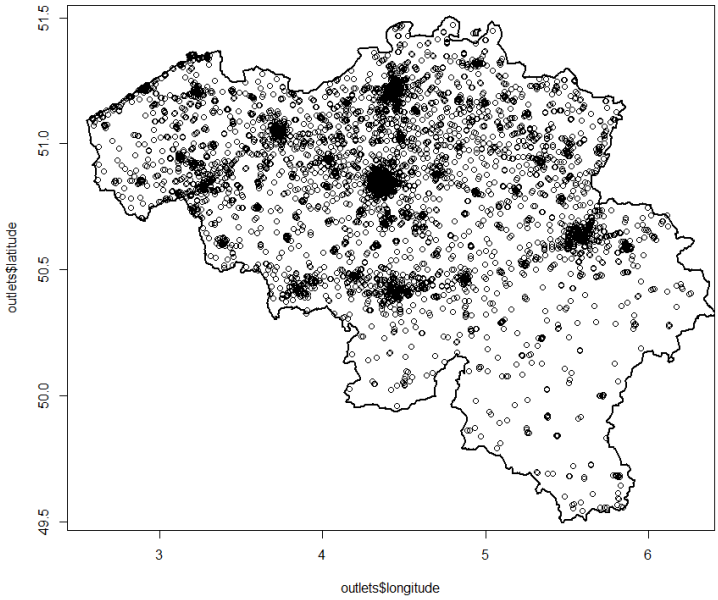
```
## We can convert the cycle_dens output into a spatial grid for further spatial analysis.
temp=SpatialPoints(expand.grid(x=cycle_dens$eval.points[,1], y=cycle_dens$eval.points[,2]))
temp = SpatialPixelsDataFrame(temp, data.frame(kde = array(cycle_dens$estimate,
                                        length(cycle_dens$estimate))))

sel=over(temp,lon_city)
str(sel)
temp2 <- temp[!is.na(sel[, 1]), ]
temp2 <- temp2[lon_city, ]

image(temp2)
plot(lon_city, add=T, lwd=2)
points(cycle$X, cycle$Y)
title("Density of London Cycle Hire Bikes in the City of London")
```



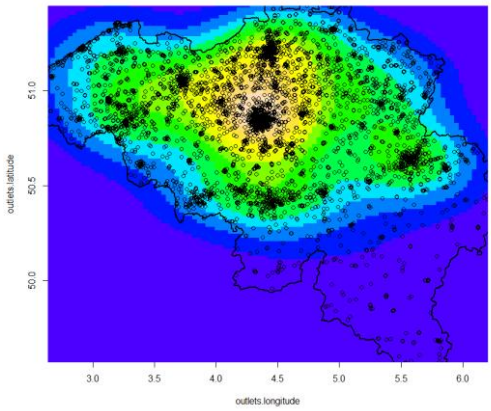
```
# Example 11
# same excercise as example 10
# data : polygon shapefile & csv-pointfile

setwd("c:/R/Rdata")
outlets <- read.csv("outletlatlon.csv",header=T,sep=";")
str(outlets)
plot(outlets$longitude,outlets$latitude)
```



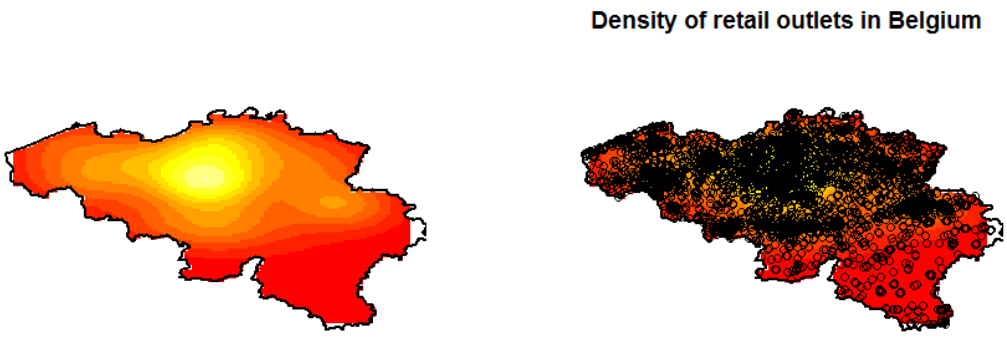

```
library(maptools)
belgie <- readShapePoly("bel_adm0.shp")
summary(belgie)
plot(outlets$longitude,outlets$latitude)
plot(belgie,add=TRUE,lwd=2)
```



```
# create a kernel density surface based on the locations of the points
# we use the sm.density function in the sm package
library(sm)
outlets_dens <-
sm.density(data.frame(outlets$longitude,outlets$latitude),display="image",ngrid=100)
# add the points and the polygon
points(outlets$longitude,outlets$latitude)
plot(belgie,add=T,lwd=2)
```




```
## We can convert the cycle_dens output into a spatial grid for further spatial analysis.
temp=SpatialPoints(expand.grid(x=outlets_dens$eval.points[,1], y=outlets_dens$eval.points[,2]))
temp = SpatialPixelsDataFrame(temp, data.frame(kde = array(outlets_dens$estimate,
                                        length(outlets_dens$estimate))))
sel=over(temp,belgie)
str(sel)
temp2 <- temp[!is.na(sel[, 1]), ]
temp2 <- temp2[belgie, ]
image(temp2)
plot(belgie, add=T, lwd=2)
points(outlets$longitude, outlets$latitude)
title("Density of retail outlets in Belgium")
```



Example 12 : data from OpenStreetmap

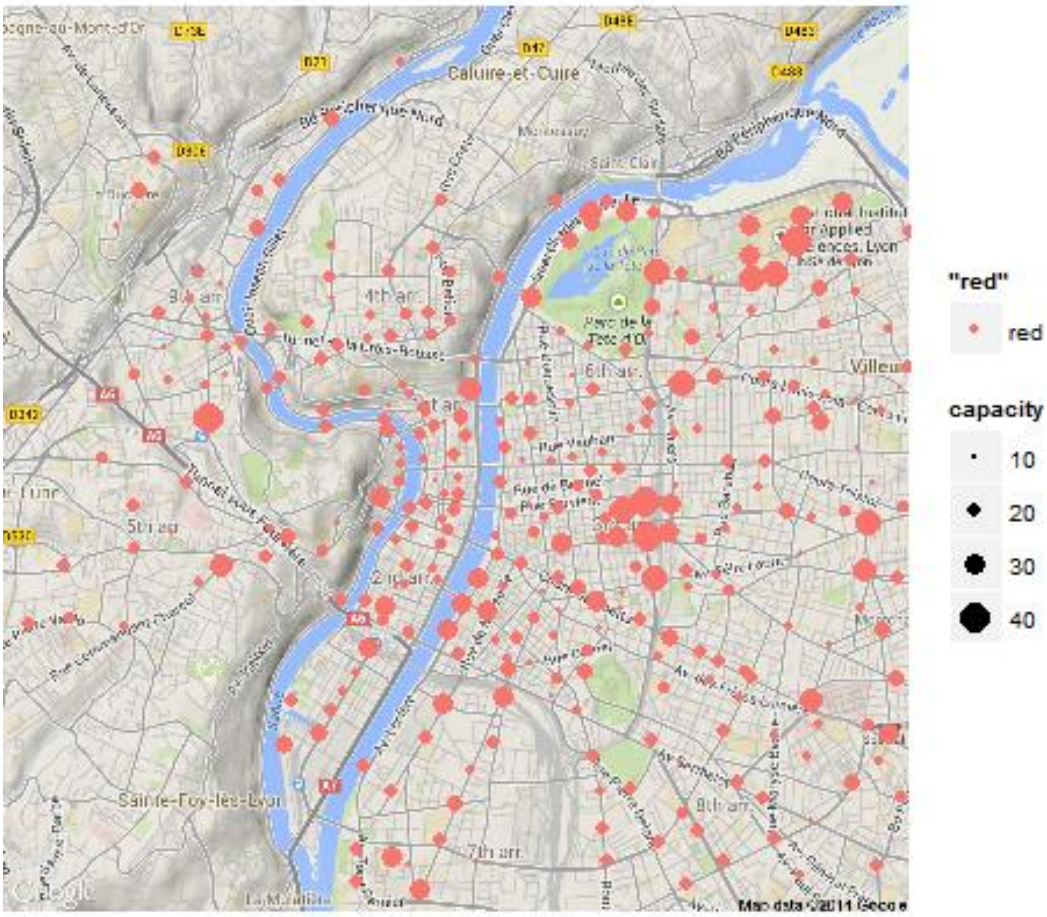
```
library(osmar)
library(sp)
library(XML)
library(rgdal)
osm.xml <- getURL("http://overpass-
api.de/api/interpreter?data=node[amenity=bicycle_rental](45.64,4.57,45.86,5.12);out;",
.encoding="UTF-8")
osm.xml <- xmlParse(osm.xml)
xmlSApply(xmlRoot(osm.xml), addAttributes,
        "version"=1,
        "timestamp"="2000-01-01T01:01:01Z",
        "uid"=1,
        "user"="a",
        "changeset"=1)
stations <- as_osmar(osm.xml)
#Fonction qui ajoute les tags OSM au slot attrs d'un objet osmar pour conversion vers sp
addtags <- function(obj){
 tag <- obj$nodes$tags
 tagf <- reshape(tag, idvar="id", timevar="k", direction="wide")
 colnames(tagf)[-1] <- substr(colnames(tagf)[-1], 3, 100000)
 obj$nodes$attrs <- merge(obj$nodes$attrs, tagf, by="id", all.x=TRUE)
 return(obj)
}
stations <- addtags(stations)
stations <- as_sp(stations, what="points")
str(stations)
```

```
> str(stations)
Formal class 'SpatialPointsDataFrame' [package "sp"] with 5 slots
  ..@ data       :'data.frame':       350 obs. of  24 variables:
  .. ..$ id              : num [1:350] 2.75e+07 3.50e+07 3.50e+07 3.50e+07 2.47e+08 ...
  .. ..$ visible         : Factor w/ 0 levels: NA NA NA NA NA NA NA NA NA NA ...
  .. ..$ timestamp       : POSIXlt[1:350], format: "2000-01-01 01:01:01" "2000-01-01 01:01:01" "2000-01-01 01:01:01" "2000-
01-01 01:01:01" ...
  .. ..$ version         : num [1:350] 1 1 1 1 1 1 1 1 1 1 ...
  .. ..$ changeset       : num [1:350] 1 1 1 1 1 1 1 1 1 1 ...
  .. ..$ user            : Factor w/ 1 level "a": 1 1 1 1 1 1 1 1 1 1 ...
  .. ..$ uid             : Factor w/ 1 level "1": 1 1 1 1 1 1 1 1 1 1 ...
  .. ..$ lat             : num [1:350] 45.7 45.7 45.7 45.8 45.7 ...
  .. ..$ lon             : num [1:350] 4.86 4.78 4.8 4.8 4.87 ...
  .. ..$ amenity         : Factor w/ 1054 levels "-","10","10 rue KrÃ¼ger",..: 557 557 557 557 557 557 557 557 557 557 ...
  .. ..$ capacity        : Factor w/ 1054 levels "-","10","10 rue KrÃ¼ger",..: 120 171 116 126 137 137 126 117 191 111 ...
  .. ..$ description     : Factor w/ 1054 levels "-","10","10 rue KrÃ¼ger",..: 992 828 958 849 854 250 493 489 241 508 ...
  .. ..$ name            : Factor w/ 1054 levels "-","10","10 rue KrÃ¼ger",..: 1012 585 743 848 733 776 552 888 914 867 ...
  .. ..$ network         : Factor w/ 1054 levels "-","10","10 rue KrÃ¼ger",..: 1041 1041 1041 1041 1041 1041 1041 1041 1041
1041 ...
  .. ..$ operator        : Factor w/ 1054 levels "-","10","10 rue KrÃ¼ger",..: 730 730 730 730 730 730 730 730 730 730 ...
  .. ..$ ref             : Factor w/ 1054 levels "-","10","10 rue KrÃ¼ger",..: 410 301 302 288 403 424 138 25 372 219 ...
  .. ..$ source          : Factor w/ 1054 levels "-","10","10 rue KrÃ¼ger",..: 756 756 756 756 756 756 756 756 756 756 ...
  .. ..$ wheelchair      : Factor w/ 1054 levels "-","10","10 rue KrÃ¼ger",..: NA NA NA NA NA NA NA NA NA NA ...
  .. ..$ note            : Factor w/ 1054 levels "-","10","10 rue KrÃ¼ger",..: NA NA NA NA NA NA NA NA NA NA ...
  .. ..$ addr:street     : Factor w/ 1054 levels "-","10","10 rue KrÃ¼ger",..: NA NA NA NA NA NA NA NA NA NA ...
  .. ..$ noexit          : Factor w/ 1054 levels "-","10","10 rue KrÃ¼ger",..: NA NA NA NA NA NA NA NA NA NA ...
  .. ..$ addr:housenumber: Factor w/ 1054 levels "-","10","10 rue KrÃ¼ger",..: NA NA NA NA NA NA NA NA NA NA ...
  .. ..$ fixme           : Factor w/ 1054 levels "-","10","10 rue KrÃ¼ger",..: NA NA NA NA NA NA NA NA NA NA ...
  .. ..$ information     : Factor w/ 1054 levels "-","10","10 rue KrÃ¼ger",..: NA NA NA NA NA NA NA NA NA NA ...
  ..@ coords.nrs : num(0)
  ..@ coords     : num [1:350, 1:2] 4.86 4.78 4.8 4.8 4.87 ...
  .. ..- attr(*, "dimnames")=List of 2
  .. .. ..$ : chr [1:350] "27543017" "34969811" "34969812" "34969813" ...
  .. .. ..$ : chr [1:2] "lon" "lat"
  ..@ bbox       : num [1:2, 1:2] 4.78 45.72 4.94 45.8
  .. ..- attr(*, "dimnames")=List of 2
  .. .. ..$ : chr [1:2] "lon" "lat"
  .. .. ..$ : chr [1:2] "min" "max"
  ..@ proj4string:Formal class 'CRS' [package "sp"] with 1 slots
  .. .. ..@ projargs: chr "+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs +towgs84=0,0,0"
```

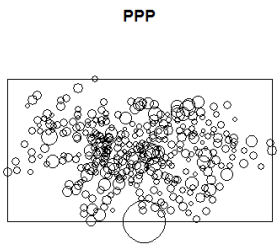
```
stations$capacity <- as.numeric(as.character(stations@data$capacity))
stations <- stations[which(stations$capacity > 0 & !is.na(stations$capacity)),]
str(stations)
velodata <- cbind(stations$lon,stations$lat,stations$capacity)
velodata <- as.data.frame(velodata)
colnames(velodata) <- c("lon","lat","capacity")
str(velodata)
```

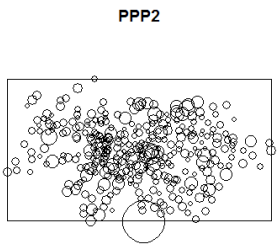
```
> str(velodata)
'data.frame':  347 obs. of  3 variables:
 $ lon     : num  4.86 4.78 4.8 4.8 4.87 ...
 $ lat     : num  45.7 45.7 45.7 45.8 45.7 ...
 $ capacity: num  17 22 15 18 20 20 18 16 30 13 ...
```

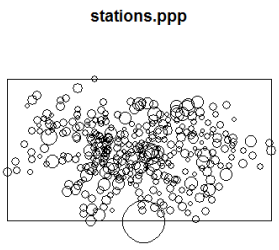
```
library(ggmap)
lyon <- get_map("Lyon,France",zoom=13,source="google")
lyon <- ggmap(lyon,extent="device")
lyon
lyon + geom_point(data=velodata,aes(x=lon,y=lat,size=capacity,color="red"))
```



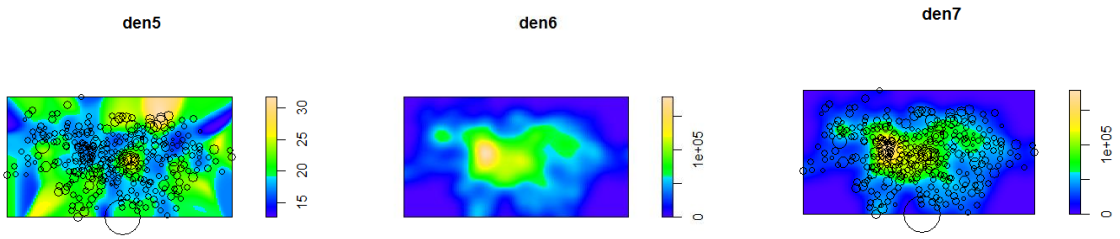
```
# creation of a function to use a ggmap object outside of get_map()
plotMAP <- function (x, bbox=NULL, crs="+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs
+towgs84=0,0,0") {
 require(raster)
 lyr.bb <- as.numeric(attr(x, "bb"))
 lyr.m <- as.matrix(x)
 lyr.m.rgb <- apply(lyr.m, 2, col2rgb)
 lyr.a.rgb <- array(dim=c(dim(lyr.m),3))
 lyr.a.rgb[,,1] <- lyr.m.rgb[seq(from=1, to=dim(lyr.m.rgb)[1]-2, by=3), ]
 lyr.a.rgb[,,2] <- lyr.m.rgb[seq(from=2, to=dim(lyr.m.rgb)[1]-1, by=3), ]
 lyr.a.rgb[,,3] <- lyr.m.rgb[seq(from=3, to=dim(lyr.m.rgb)[1], by=3), ]
 lyr.brick <- brick(lyr.a.rgb, xmn=lyr.bb[2], xmx=lyr.bb[4], ymn=lyr.bb[1], ymx=lyr.bb[3], crs=crs)
 xsize <- lyr.brick@extent@xmax - lyr.brick@extent@xmin
 ysize <- lyr.brick@extent@ymax - lyr.brick@extent@ymin
 ratio <- max(xsize, ysize) / min(xsize, ysize)
 if (is.null(bbox)){
  plotRGB(lyr.brick, asp=ratio)
 } else {
  ext <- extent(bbox)
  plotRGB(lyr.brick, asp=ratio, ext=ext)
 }
}

library(spatstat)
min(stations$lon)
max(stations$lon)
min(stations$lat)
max(stations$lat)
PPP <-
ppp(stations$lon,stations$lat,c(4.783902,4.920609),c(45.72417,45.7974),marks=stations$capacity)
plot(PPP)
bb <- bounding.box(PPP)
bb
W <- as(bb,"owin")
PPP2 <- ppp(stations$lon,stations$lat,window=W,marks=stations$capacity)
plot(PPP2)
stations.ppp <- ppp(coordinates(stations)[,1], coordinates(stations)[,2],
window=W,marks=stations$capacity)
plot(stations.ppp)
```







```
r <- bw.diggle(stations.ppp)
r
den5 <- Smooth(stations.ppp,0.00442278)
plot(den5)
plot(stations.ppp,add=T)
den6 <- density(stations.ppp,0.00442278)
plot(den6)
den7 <- density(stations.ppp,sigma=0.00442278,weights=stations$capacity)
plot(den7)
plot(stations.ppp,add=T)
```

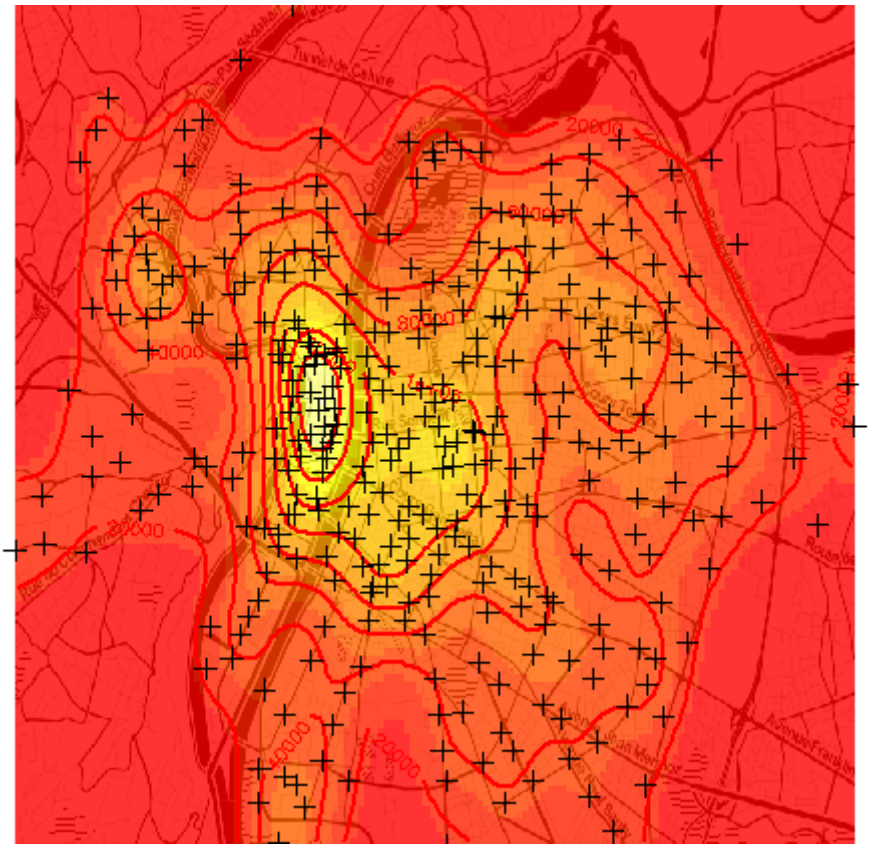



```
stations.den <- as(den7,"SpatialGridDataFrame")
summary(stations.den)
```

```
 > summary(stations.den)
Object of class SpatialGridDataFrame
Coordinates:
            min       max
[1,]  4.783902  4.920609
[2,] 45.724349 45.797396
Is projected: NA
proj4string : [NA]
Grid attributes:
  cellcentre.offset     cellsize cells.dim
1          4.784436 0.0010680180       128
2         45.724634 0.0005706812       128
Data attributes:
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
      0    7484   27880   34750   50910  178600
```

```
lyonraster <- get_map(bbox(stations.den), zoom=13, source="stamen", maptype="toner")
plotMAP(lyonraster)
```

```
image(stations.den, col = heat.colors(12, alpha=0.8), add=T)
contour(stations.den, col=2, lwd=2, add=T)
plot(stations, add=T)
```

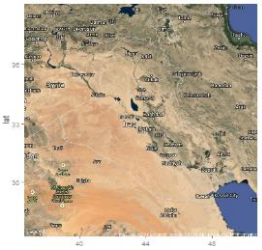


Example 13 : point analysis Wikileaks Iraq Data

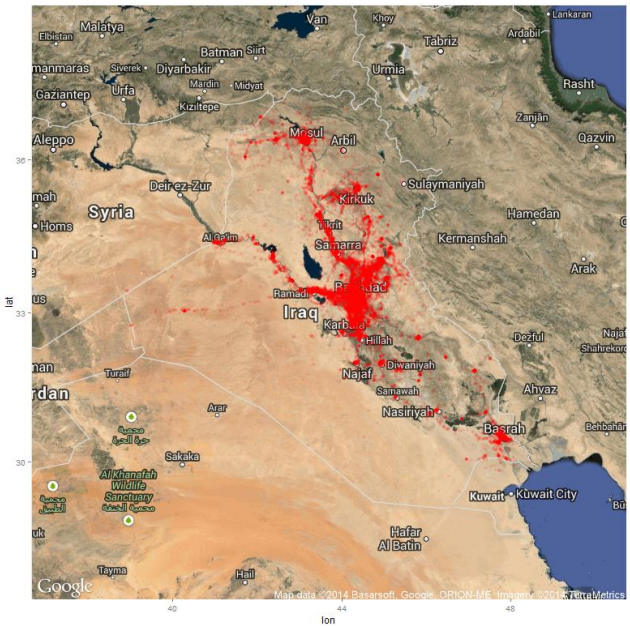
```
setwd("c:/R/Rdata")
deaths <- read.csv("Deaths only.csv",header=TRUE,sep=",")
str(deaths)
levels(deaths$Type)
deaths$Type <- sub(deaths$Type,pattern="CRIMINAL EVENT",replacement="Criminal Event")
deaths$Type <- sub(deaths$Type,pattern="criminal event",replacement="Criminal Event")
deaths$Type <- sub(deaths$Type,pattern="EXPLOSIVE HAZARD",replacement="Explosive Hazard")
deaths$Type <- factor(deaths$Type)
levels(deaths$Type)
```

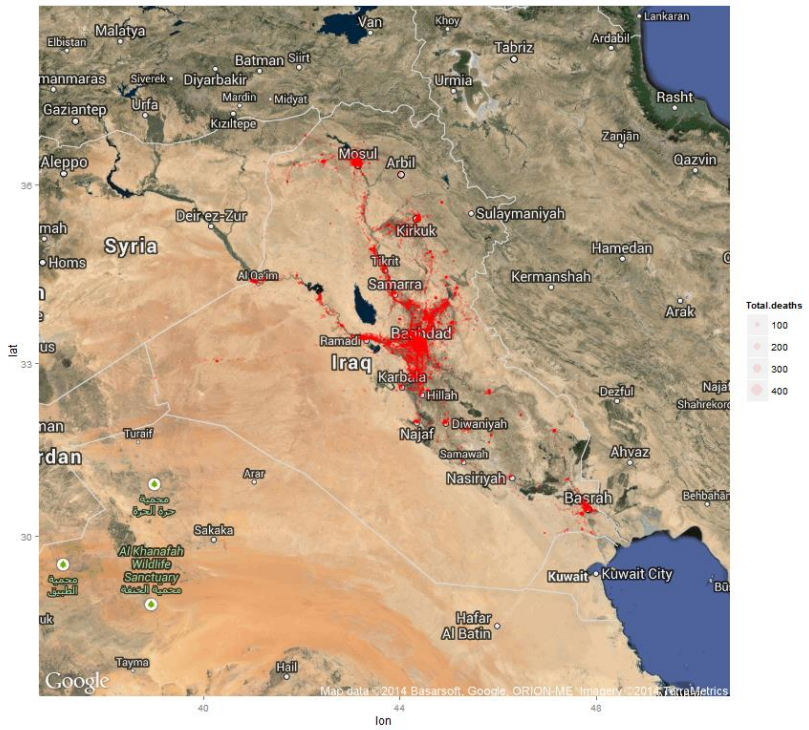
```
> str(deaths)
'data.frame':         52048 obs. of  19 variables:
 $ Report.key             : Factor w/ 52048 levels "00023432-98D1-7C41-A16F6C4DC998257A",..: 30731 30841
30879 30884 20882 31079 30929 31033 30933 31048 ...
 $ Date.and.time          : Factor w/ 43512 levels "01/01/2004 03:00",..: 1 2 3 4 4 1348 1349 1350 1351
1352 ...
 $ Type                   : Factor w/ 12 levels "criminal event",..: 9 9 2 7 2 7 5 5 4 4 ...
 $ Category               : Factor w/ 86 levels "","Accident",..: 2 2 55 58 5 15 34 34 25 43 ...
 $ Title                  : Factor w/ 39015 levels "","(12TH IMAM) MURDER OF CIV IN ARAB YASIN (ZONE 415);
1 CIV KILLED, 0 CF INJ/DAMAG",..: 24412 15643 37998 24448 37817 24591 24876 15701 33835 30645 ...
 $ Region                 : Factor w/ 8 levels "","MND-BAGHDAD",..: 2 8 4 7 7 8 8 3 8 4 ...
 $ Attack.on              : Factor w/ 3 levels "ENEMY","FRIEND",..: 3 3 1 2 1 2 1 1 1 1 ...
 $ Coalition.forces.wounded: int  0 6 0 0 0 0 1 3 1 5 ...
 $ Coalition.forces.killed : int  2 1 0 0 0 0 1 2 1 1 ...
 $ Iraq.forces.wounded    : int  0 0 0 0 0 0 0 0 0 0 ...
 $ Iraq.forces.killed     : int  0 0 0 0 0 0 0 0 0 0 ...
 $ Civilian.wia           : int  0 0 0 0 2 0 0 0 0 0 ...
 $ Civilian.kia           : int  0 0 1 0 1 0 0 0 0 0 ...
 $ Enemy.wia              : int  0 0 0 2 0 0 0 0 0 0 ...
 $ Enemy.kia              : int  0 0 0 1 0 4 0 0 0 0 ...
 $ Enemy.detained         : int  0 0 0 0 0 6 0 0 0 3 ...
 $ Total.deaths           : int  2 1 1 1 1 4 1 2 1 1 ...
 $ Latitude               : num  33.3 33.2 36.4 31.1 31.1 ...
 $ Longitude              : num  44.4 43.4 43.2 46.2 46.2 ...
> levels(deaths$Type)
 [1] "criminal event"      "Criminal Event"      "CRIMINAL EVENT"      "Enemy Action"        "Explosive
Hazard"    "EXPLOSIVE HAZARD"
 [7] "Friendly Action"     "Friendly Fire"       "Non-Combat Event"    "Other"               "Suspicious
Incident" "Threat Report"
> deaths$Type <- sub(deaths$Type,pattern="CRIMINAL EVENT",replacement="Criminal Event")
> deaths$Type <- sub(deaths$Type,pattern="criminal event",replacement="Criminal Event")
> deaths$Type <- sub(deaths$Type,pattern="EXPLOSIVE HAZARD",replacement="Explosive Hazard")
> deaths$Type <- factor(deaths$Type)
> levels(deaths$Type)
[1] "Criminal Event"      "Enemy Action"        "Explosive Hazard"    "Friendly Action"     "Friendly Fire"
"Non-Combat Event"
[7] "Other"               "Suspicious Incident" "Threat Report"
```

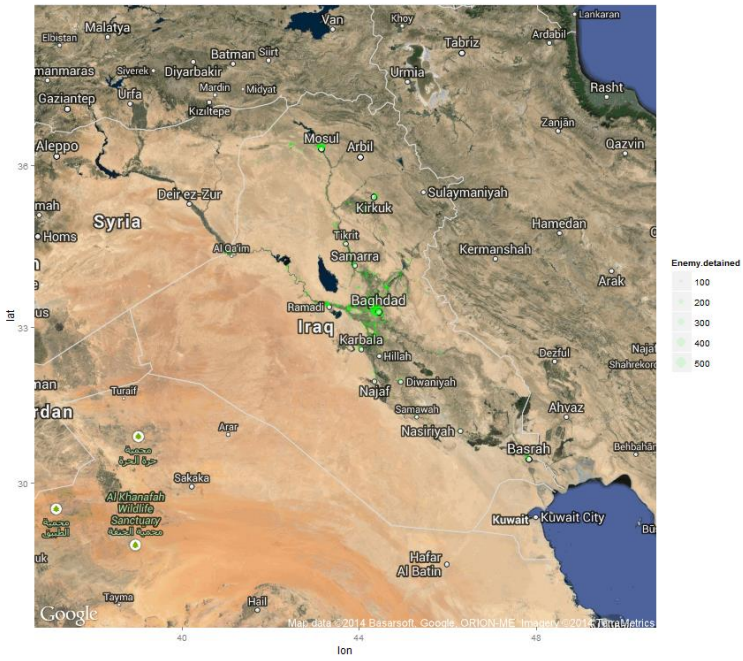
```
# create a map with GGMAP
library(ggmap)
library(sp)
library(rgdal)
map <- get_map(location="Iraq",maptype="hybrid",zoom=6)
ggmap(map,extent="panel")
```



```
# put the data on the map
ggmap(map,extent="panel") +
geom_point(data=deaths,aes(x=Longitude,y=Latitude),alpha=0.1,color="red")

ggmap(map,extent="panel") +
geom_point(data=deaths,aes(x=Longitude,y=Latitude,size=Total.deaths),alpha=0.1,color="red")

ggmap(map,extent="panel") +
        geom_point(data=deaths[deaths$Enemy.detained > 0, ],
                        aes(x=Longitude,y=Latitude,size=Enemy.detained),alpha=0.1,color="green")
```








```
# create a spatialpointsdataframe from the coordinates in deaths
class(deaths)
deaths.spp <- SpatialPointsDataFrame(coords=deaths[,18:19],proj4string=CRS("+proj=longlat
                                                +ellps=WGS84 +datum=WGS84 +no_defs"),data=deaths)
class(deaths.spp)
str(deaths.spp)
proj4string(deaths.spp)
```

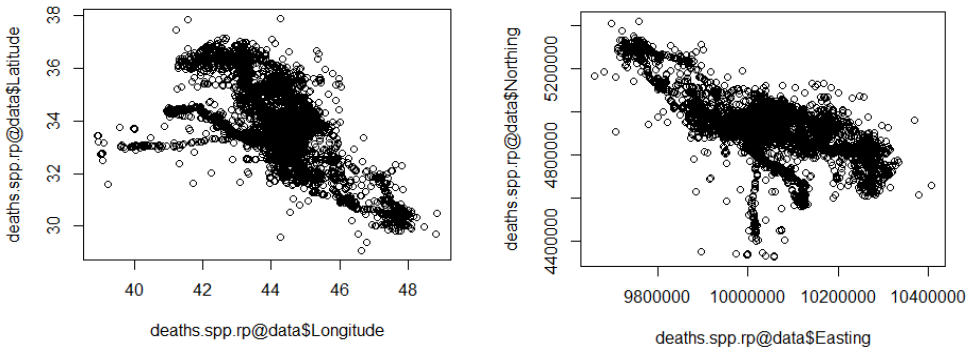
```
> class(deaths.spp)
[1] "SpatialPointsDataFrame"
attr(,"package")
[1] "sp"
> str(deaths.spp)
Formal class 'SpatialPointsDataFrame' [package "sp"] with 5 slots
  ..@ data       :'data.frame':  52048 obs. of  19 variables:
  .. ..$ Report.key              : Factor w/ 52048 levels "00023432-98D1-7C41-A16F6C4DC998257A",..: 30731
30841 30879 30884 20882 31079 30929 31033 30933 31048 ...
  .. ..$ Date.and.time           : Factor w/ 43512 levels "01/01/2004 03:00",..: 1 2 3 4 4 1348 1349 1350
1351 1352 ...
  .. ..$ Type                    : Factor w/ 9 levels "Criminal Event",..: 6 6 1 4 1 4 3 3 2 2 ...
  .. ..$ Category                : Factor w/ 86 levels "","Accident",..: 2 2 55 58 5 15 34 34 25 43 ...
  .. ..$ Title                   : Factor w/ 39015 levels "","(12TH IMAM) MURDER OF CIV IN ARAB YASIN (ZONE
415); 1 CIV KILLED, 0 CF INJ/DAMAG",..: 24412 15643 37998 24448 37817 24591 24876 15701 33835 30645 ...
  .. ..$ Region                  : Factor w/ 8 levels "","MND-BAGHDAD",..: 2 8 4 7 7 8 8 3 8 4 ...
  .. ..$ Attack.on               : Factor w/ 3 levels "ENEMY","FRIEND",..: 3 3 1 2 1 2 1 1 1 1 ...
  .. ..$ Coalition.forces.wounded: int [1:52048] 0 6 0 0 0 0 1 3 1 5 ...
  .. ..$ Coalition.forces.killed : int [1:52048] 2 1 0 0 0 0 1 2 1 1 ...
  .. ..$ Iraq.forces.wounded     : int [1:52048] 0 0 0 0 0 0 0 0 0 0 ...
  .. ..$ Iraq.forces.killed      : int [1:52048] 0 0 0 0 0 0 0 0 0 0 ...
  .. ..$ Civilian.wia            : int [1:52048] 0 0 0 0 2 0 0 0 0 0 ...
  .. ..$ Civilian.kia            : int [1:52048] 0 0 1 0 1 0 0 0 0 0 ...
  .. ..$ Enemy.wia               : int [1:52048] 0 0 0 2 0 0 0 0 0 0 ...
  .. ..$ Enemy.kia               : int [1:52048] 0 0 0 1 0 4 0 0 0 0 ...
  .. ..$ Enemy.detained          : int [1:52048] 0 0 0 0 0 6 0 0 0 3 ...
  .. ..$ Total.deaths            : int [1:52048] 2 1 1 1 1 4 1 2 1 1 ...
  .. ..$ Latitude                : num [1:52048] 33.3 33.2 36.4 31.1 31.1 ...
  .. ..$ Longitude               : num [1:52048] 44.4 43.4 43.2 46.2 46.2 ...
  ..@ coords.nrs : num(0)
  ..@ coords     : num [1:52048, 1:2] 33.3 33.2 36.4 31.1 31.1 ...
  .. ..- attr(*, "dimnames")=List of 2
  .. .. ..$ : NULL
  .. .. ..$ : chr [1:2] "Latitude" "Longitude"
  ..@ bbox       : num [1:2, 1:2] 29.1 38.9 37.9 48.9
  .. ..- attr(*, "dimnames")=List of 2
  .. .. ..$ : chr [1:2] "Latitude" "Longitude"
  .. .. ..$ : chr [1:2] "min" "max"
  ..@ proj4string:Formal class 'CRS' [package "sp"] with 1 slots
  .. .. ..@ projargs: chr "+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs +towgs84=0,0,0"
> proj4string(deaths.spp)
[1] "+proj=longlat +ellps=WGS84 +datum=WGS84 +no_defs +towgs84=0,0,0"
```

```
# reproject data into meters
deaths.spp.rp <- spTransform(deaths.spp,CRS("+init=epsg:3839"))
proj4string(deaths.spp.rp)
str(deaths.spp.rp)

deaths.spp.rp$Easting <- coordinates(deaths.spp.rp)[,1]
deaths.spp.rp$Northing <- coordinates(deaths.spp.rp)[,2]
str(deaths.spp.rp)
```

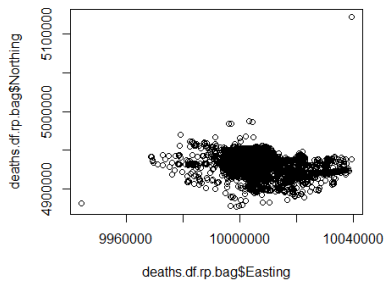
```
> # reproject data into meters
> deaths.spp.rp <- spTransform(deaths.spp,CRS("+init=epsg:3839"))
> proj4string(deaths.spp.rp)
[1] "+init=epsg:3839 +proj=tmerc +lat_0=0 +lon_0=27 +k=1 +x_0=9500000 +y_0=0 +ellps=krass
+units=m +no_defs"
> str(deaths.spp.rp)
Formal class 'SpatialPointsDataFrame' [package "sp"] with 5 slots
  ..@ data       :'data.frame':       52048 obs. of  19 variables:
  .. ..$ Report.key              : Factor w/ 52048 levels "00023432-98D1-7C41-
A16F6C4DC998257A",..: 30731 30841 30879 30884 20882 31079 30929 31033 30933 31048 ...
  .. ..$ Date.and.time           : Factor w/ 43512 levels "01/01/2004 03:00",..: 1 2 3 4 4
1348 1349 1350 1351 1352 ...
  .. ..$ Type                    : Factor w/ 9 levels "Criminal Event",..: 6 6 1 4 1 4 3 3 2 2
...
  .. ..$ Category                : Factor w/ 86 levels "","Accident",..: 2 2 55 58 5 15 34 34
25 43 ...
  .. ..$ Title                   : Factor w/ 39015 levels "","(12TH IMAM) MURDER OF CIV IN
ARAB YASIN (ZONE 415); 1 CIV KILLED, 0 CF INJ/DAMAG",..: 24412 15643 37998 24448 37817 24591
24876 15701 33835 30645 ...
  .. ..$ Region                  : Factor w/ 8 levels "","MND-BAGHDAD",..: 2 8 4 7 7 8 8 3 8 4
...
  .. ..$ Attack.on               : Factor w/ 3 levels "ENEMY","FRIEND",..: 3 3 1 2 1 2 1 1 1 1
...
  .. ..$ Coalition.forces.wounded: int [1:52048] 0 6 0 0 0 0 1 3 1 5 ...
  .. ..$ Coalition.forces.killed : int [1:52048] 2 1 0 0 0 0 1 2 1 1 ...
  .. ..$ Iraq.forces.wounded     : int [1:52048] 0 0 0 0 0 0 0 0 0 0 ...
  .. ..$ Iraq.forces.killed      : int [1:52048] 0 0 0 0 0 0 0 0 0 0 ...
  .. ..$ Civilian.wia            : int [1:52048] 0 0 0 0 2 0 0 0 0 0 ...
  .. ..$ Civilian.kia            : int [1:52048] 0 0 1 0 1 0 0 0 0 0 ...
  .. ..$ Enemy.wia               : int [1:52048] 0 0 0 2 0 0 0 0 0 0 ...
  .. ..$ Enemy.kia               : int [1:52048] 0 0 0 1 0 4 0 0 0 0 ...
  .. ..$ Enemy.detained          : int [1:52048] 0 0 0 0 0 0 6 0 0 0 3 ...
  .. ..$ Total.deaths            : int [1:52048] 2 1 1 1 1 4 1 2 1 1 ...
  .. ..$ Latitude                : num [1:52048] 33.3 33.2 36.4 31.1 31.1 ...
  .. ..$ Longitude               : num [1:52048] 44.4 43.4 43.2 46.2 46.2 ...
  ..@ coords.nrs : num(0)
  ..@ coords     : num [1:52048, 1:2] 10001983 10000759 10262898 9813252 9813252 ...
  .. ..- attr(*, "dimnames")=List of 2
  .. .. ..$ : NULL
  .. .. ..$ : chr [1:2] "Latitude" "Longitude"
  ..@ bbox       : num [1:2, 1:2] 9659349 4328170 10407350 5420184
  .. ..- attr(*, "dimnames")=List of 2
  .. .. ..$ : chr [1:2] "Latitude" "Longitude"
  .. .. ..$ : chr [1:2] "min" "max"
  ..@ proj4string:Formal class 'CRS' [package "sp"] with 1 slots
  .. .. ..@ projargs: chr "+init=epsg:3839 +proj=tmerc +lat_0=0 +lon_0=27 +k=1 +x_0=9500000
+y_0=0 +ellps=krass +units=m +no_defs"
>
> deaths.spp.rp$Easting <- coordinates(deaths.spp.rp)[,1]
> deaths.spp.rp$Northing <- coordinates(deaths.spp.rp)[,2]
> str(deaths.spp.rp)
Formal class 'SpatialPointsDataFrame' [package "sp"] with 5 slots
  ..@ data       :'data.frame':       52048 obs. of  21 variables:
  .. ..$ Report.key              : Factor w/ 52048 levels "00023432-98D1-7C41-
A16F6C4DC998257A",..: 30731 30841 30879 30884 20882 31079 30929 31033 30933 31048 ...
  .. ..$ Date.and.time           : Factor w/ 43512 levels "01/01/2004 03:00",..: 1 2 3 4 4
1348 1349 1350 1351 1352 ...
  .. ..$ Type                    : Factor w/ 9 levels "Criminal Event",..: 6 6 1 4 1 4 3 3 2 2
...
  .. ..$ Category                : Factor w/ 86 levels "","Accident",..: 2 2 55 58 5 15 34 34
25 43 ...
  .. ..$ Title                   : Factor w/ 39015 levels "","(12TH IMAM) MURDER OF CIV IN
ARAB YASIN (ZONE 415); 1 CIV KILLED, 0 CF INJ/DAMAG",..: 24412 15643 37998 24448 37817 24591
24876 15701 33835 30645 ...
  .. ..$ Region                  : Factor w/ 8 levels "","MND-BAGHDAD",..: 2 8 4 7 7 8 8 3 8 4
...
  .. ..$ Attack.on               : Factor w/ 3 levels "ENEMY","FRIEND",..: 3 3 1 2 1 2 1 1 1 1
...
  .. ..$ Coalition.forces.wounded: int [1:52048] 0 6 0 0 0 0 1 3 1 5 ...
  .. ..$ Coalition.forces.killed : int [1:52048] 2 1 0 0 0 0 1 2 1 1 ...
  .. ..$ Iraq.forces.wounded     : int [1:52048] 0 0 0 0 0 0 0 0 0 0 ...
```

```
  .. ..$ Iraq.forces.killed      : int [1:52048] 0 0 0 0 0 0 0 0 0 0 ...
  .. ..$ Civilian.wia            : int [1:52048] 0 0 0 0 2 0 0 0 0 0 ...
  .. ..$ Civilian.kia            : int [1:52048] 0 0 1 0 1 0 0 0 0 0 ...
  .. ..$ Enemy.wia               : int [1:52048] 0 0 0 2 0 0 0 0 0 0 ...
  .. ..$ Enemy.kia               : int [1:52048] 0 0 0 1 0 4 0 0 0 0 ...
  .. ..$ Enemy.detained          : int [1:52048] 0 0 0 0 0 6 0 0 0 3 ...
  .. ..$ Total.deaths            : int [1:52048] 2 1 1 1 1 4 1 2 1 1 ...
  .. ..$ Latitude                : num [1:52048] 33.3 33.2 36.4 31.1 31.1 ...
  .. ..$ Longitude               : num [1:52048] 44.4 43.4 43.2 46.2 46.2 ...
  .. ..$ Easting                 : num [1:52048] 10001983 10000759 10262898 9813252 9813252
...
  .. ..$ Northing                : num [1:52048] 4936602 4826227 4824171 5125026 5125026 ...
  ..@ coords.nrs : num(0)
  ..@ coords     : num [1:52048, 1:2] 10001983 10000759 10262898 9813252 9813252 ...
  .. ..- attr(*, "dimnames")=List of 2
  .. .. ..$ : NULL
  .. .. ..$ : chr [1:2] "Latitude" "Longitude"
  ..@ bbox       : num [1:2, 1:2] 9659349 4328170 10407350 5420184
  .. ..- attr(*, "dimnames")=List of 2
  .. .. ..$ : chr [1:2] "Latitude" "Longitude"
  .. .. ..$ : chr [1:2] "min" "max"
  ..@ proj4string:Formal class 'CRS' [package "sp"] with 1 slots
  .. .. ..@ projargs: chr "+init=epsg:3839 +proj=tmerc +lat_0=0 +lon_0=27 +k=1 +x_0=9500000
+y_0=0 +ellps=krass +units=m +no_defs"
```

plot(deaths.spp.rp@data$Longitude,deaths.spp.rp@data$Latitude)
plot(deaths.spp.rp@data$Easting,deaths.spp.rp@data$Northing)



# focus on the region of Baghdad
deaths.df.rp.bag <- deaths.spp.rp@data[deaths.spp.rp@data$Region=="MND-BAGHDAD",]
# note that this is NOT a spatial data frame (the selection is done on ..@data !)
class(deaths.df.rp.bag)
str(deaths.df.rp.bag)
plot(deaths.df.rp.bag$Easting,deaths.df.rp.bag$Northing)



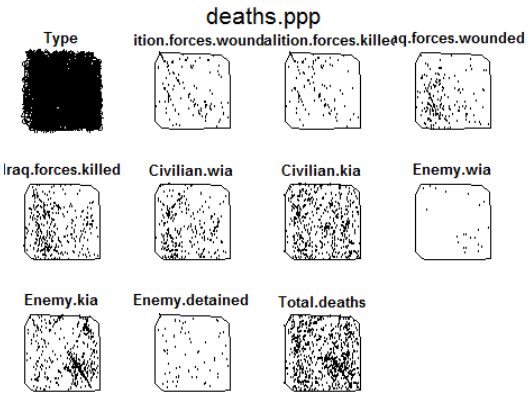
```
# select data within a given bounds
deaths.df.rp.bag <- deaths.df.rp.bag[(deaths.df.rp.bag$Northing < 4950000 &
deaths.df.rp.bag$Northing > 4940000) &
                        (deaths.df.rp.bag$Easting > 10000000 & deaths.df.rp.bag$Easting < 10010000),]
str(deaths.df.rp.bag)
plot(deaths.df.rp.bag$Easting,deaths.df.rp.bag$Northing)
deaths.df.rp.bag <- na.omit(deaths.df.rp.bag)

library(spatstat)
deaths.chull <- convexhull.xy(x=deaths.df.rp.bag$Easting,y=deaths.df.rp.bag$Northing)
plot(deaths.chull)
deaths.ppp <- ppp(x=deaths.df.rp.bag$Easting,y=deaths.df.rp.bag$Northing,window=deaths.chull,
            marks=deaths.df.rp.bag[,c(3,8:17)])
summary(deaths.ppp)
```

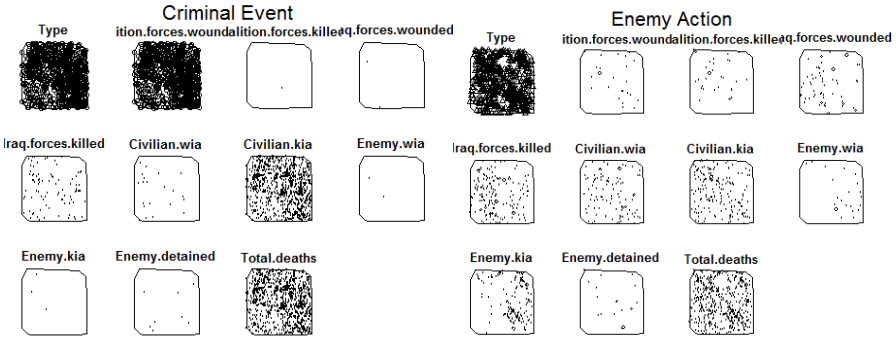
```
> str(deaths.df.rp.bag)
'data.frame':         3350 obs. of  21 variables:
 $ Report.key           : Factor w/ 52048 levels "00023432-98D1-7C41-A16F6C4DC998257A",..: 3304 3510
3597 3652 3880 3914 4038 4253 4492 4634 ...
 $ Date.and.time        : Factor w/ 43512 levels "01/01/2004 03:00",..: 15758 30055 38653 42826 18730
21748 28786 1565 23294 34569 ...
 $ Type                 : Factor w/ 9 levels "Criminal Event",..: 3 3 3 3 6 2 4 7 3 2 ...
 $ Category             : Factor w/ 86 levels "","Accident",..: 34 34 34 82 2 25 8 58 34 25 ...
 $ Title                : Factor w/ 39015 levels "","(12TH IMAM) MURDER OF CIV IN ARAB YASIN (ZONE 415);
1 CIV KILLED, 0 CF INJ/DAMAG",..: 29187 24334 38760 24383 19045 36062 30643 24605 38367 35310 ...
 $ Region               : Factor w/ 8 levels "","MND-BAGHDAD",..: 2 2 2 2 2 2 2 2 2 2 ...
 $ Attack.on            : Factor w/ 3 levels "ENEMY","FRIEND",..: 1 1 1 1 3 1 2 3 1 1 ...
 $ Coalition.forces.wounded: int  2 0 0 0 0 0 0 0 0 0 ...
 $ Coalition.forces.killed : int  1 0 0 0 0 0 0 0 0 0 ...
 $ Iraq.forces.wounded  : int  0 0 0 0 0 0 0 0 0 1 ...
 $ Iraq.forces.killed   : int  0 0 0 0 0 0 0 1 0 0 ...
 $ Civilian.wia         : int  0 0 6 2 4 0 0 0 45 0 ...
 $ Civilian.kia         : int  0 2 0 3 4 0 0 0 17 0 ...
 $ Enemy.wia            : int  0 0 0 0 0 1 0 0 0 0 ...
 $ Enemy.kia            : int  0 0 1 0 0 1 1 0 0 1 ...
 $ Enemy.detained       : int  0 0 0 0 0 1 0 0 0 0 ...
 $ Total.deaths         : int  1 2 1 3 4 1 1 1 17 1 ...
 $ Latitude             : num  33.3 33.3 33.3 33.3 33.3 ...
 $ Longitude            : num  44.5 44.5 44.4 44.5 44.5 ...
 $ Easting              : num  1e+07 1e+07 1e+07 1e+07 1e+07 ...
 $ Northing             : num  4946270 4947745 4941435 4947623 4944966 ...
> plot(deaths.df.rp.bag$Easting,deaths.df.rp.bag$Northing)
> deaths.df.rp.bag <- na.omit(deaths.df.rp.bag)
>
> library(spatstat)
Loading required package: mgcv
This is mgcv 1.7-22. For overview type 'help("mgcv-package")'.
Loading required package: deldir
deldir 0.1-1

spatstat 1.33-0       (nickname: 'Titanic Deckchair')
For an introduction to spatstat, type 'beginner'
Warning messages:
1: package 'spatstat' was built under R version 3.0.2
2: package 'deldir' was built under R version 3.0.2
> deaths.chull <- convexhull.xy(x=deaths.df.rp.bag$Easting,y=deaths.df.rp.bag$Northing)
> plot(deaths.chull)
> deaths.ppp <- ppp(x=deaths.df.rp.bag$Easting,y=deaths.df.rp.bag$Northing,window=deaths.chull,
+                   marks=deaths.df.rp.bag[,c(3,8:17)])
Warning message:
In ppp(x = deaths.df.rp.bag$Easting, y = deaths.df.rp.bag$Northing,  :
  data contain duplicated points
> summary(deaths.ppp)
Marked planar point pattern: 3350 points
Average intensity 3.47e-05 points per square unit

*Pattern contains duplicated points*

Coordinates are given to 1 decimal places
i.e. rounded to the nearest multiple of 0.1 units

Mark variables:  Type, Coalition.forces.wounded, Coalition.forces.killed, Iraq.forces.wounded,
Iraq.forces.killed, Civilian.wia, Civilian.kia, Enemy.wia, Enemy.kia, Enemy.detained, Total.deaths
Summary:
                Type      Coalition.forces.wounded Coalition.forces.killed Iraq.forces.wounded
Iraq.forces.killed  Civilian.wia
 Criminal Event  :1816   Min.   : 0.0000          Min.   :0.00000         Min.   : 0.0000     Min.   :
0.0000    Min.   :  0.00
 Explosive Hazard: 611   1st Qu.: 0.0000          1st Qu.:0.00000         1st Qu.: 0.0000     1st Qu.:
0.0000    1st Qu.:  0.00
 Enemy Action    : 592   Median : 0.0000          Median :0.00000         Median : 0.0000     Median :
0.0000    Median :  0.00
 Friendly Action : 266   Mean   : 0.1173          Mean   :0.04806         Mean   : 0.2179     Mean   :
0.1985    Mean   :  1.88
```

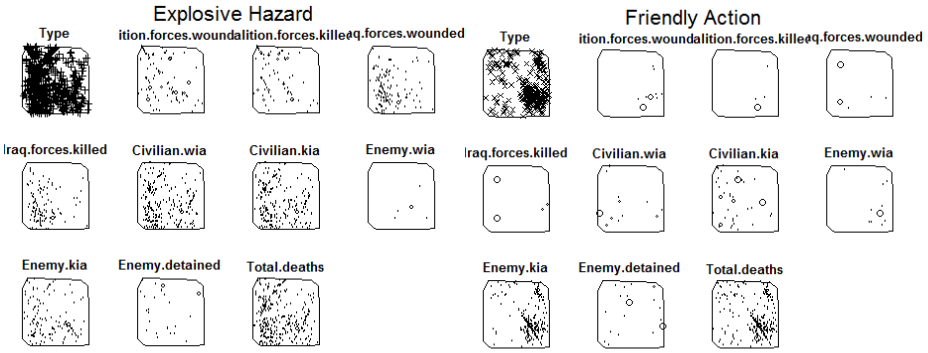
```
 Other           :  41   3rd Qu.: 0.0000          3rd Qu.:0.00000         3rd Qu.: 0.0000     3rd Qu.:
0.0000    3rd Qu.:  0.00
 Non-Combat Event:  18   Max.   :45.0000          Max.   :7.00000         Max.   :59.0000     Max.
:28.0000    Max.   :247.00
 (Other)         :   6
  Civilian.kia       Enemy.wia           Enemy.kia       Enemy.detained      Total.deaths
 Min.   :  0.000   Min.   :  0.00000   Min.   : 0.0000   Min.   : 0.00000   Min.   :  1.000
 1st Qu.:  0.000   1st Qu.:  0.00000   1st Qu.: 0.0000   1st Qu.: 0.00000   1st Qu.:  1.000
 Median :  1.000   Median :  0.00000   Median : 0.0000   Median : 0.00000   Median :  1.000
 Mean   :  1.566   Mean   :  0.09343   Mean   : 0.5101   Mean   : 0.07313   Mean   :  2.323
 3rd Qu.:  1.000   3rd Qu.:  0.00000   3rd Qu.: 0.0000   3rd Qu.: 0.00000   3rd Qu.:  2.000
 Max.   :181.000   Max.   :194.00000   Max.   :70.0000   Max.   :22.00000   Max.   :181.000


Window: polygonal boundary
single connected closed polygon with 16 vertices
enclosing rectangle: [10000045, 10009992] x [4940001, 4949997] units
Window area =  96440600 square units
>
> plot(deaths.ppp)
> plot(split(deaths.ppp))
> # select data within a given bounds
> deaths.df.rp.bag <- deaths.df.rp.bag[(deaths.df.rp.bag$Northing < 4950000 & deaths.df.rp.bag$Northing >
4940000) &
+                                      (deaths.df.rp.bag$Easting > 10000000 & deaths.df.rp.bag$Easting <
10010000),]
> str(deaths.df.rp.bag)
'data.frame':         3350 obs. of  21 variables:
 $ Report.key            : Factor w/ 52048 levels "00023432-98D1-7C41-A16F6C4DC998257A",..: 3304 3510
3597 3652 3880 3914 4038 4253 4492 4634 ...
 $ Date.and.time         : Factor w/ 43512 levels "01/01/2004 03:00",..: 15758 30055 38653 42826 18730
21748 28786 1565 23294 34569 ...
 $ Type                  : Factor w/ 9 levels "Criminal Event",..: 3 3 3 3 6 2 4 7 3 2 ...
 $ Category              : Factor w/ 86 levels "","Accident",..: 34 34 34 82 2 25 8 58 34 25 ...
 $ Title                 : Factor w/ 39015 levels "","(12TH IMAM) MURDER OF CIV IN ARAB YASIN (ZONE 415);
1 CIV KILLED, 0 CF INJ/DAMAG",..: 29187 24334 38760 24383 19045 36062 30643 24605 38367 35310 ...
 $ Region                : Factor w/ 8 levels "","MND-BAGHDAD",..: 2 2 2 2 2 2 2 2 2 2 ...
 $ Attack.on             : Factor w/ 3 levels "ENEMY","FRIEND",..: 1 1 1 1 3 1 2 3 1 1 ...
 $ Coalition.forces.wounded: int  2 0 0 0 0 0 0 0 0 0 ...
 $ Coalition.forces.killed : int  1 0 0 0 0 0 0 0 0 0 ...
 $ Iraq.forces.wounded     : int  0 0 0 0 0 0 0 0 0 1 ...
 $ Iraq.forces.killed      : int  0 0 0 0 0 0 0 1 0 0 ...
 $ Civilian.wia            : int  0 0 6 2 4 0 0 0 45 0 ...
 $ Civilian.kia            : int  0 2 0 3 4 0 0 0 17 0 ...
 $ Enemy.wia               : int  0 0 0 0 0 1 0 0 0 0 ...
 $ Enemy.kia               : int  0 0 1 0 0 1 1 0 0 1 ...
 $ Enemy.detained          : int  0 0 0 0 0 1 0 0 0 0 ...
 $ Total.deaths            : int  1 2 1 3 4 1 1 1 17 1 ...
 $ Latitude                : num  33.3 33.3 33.3 33.3 33.3 ...
 $ Longitude               : num  44.5 44.5 44.4 44.5 44.5 ...
 $ Easting                 : num  1e+07 1e+07 1e+07 1e+07 1e+07 ...
 $ Northing                : num  4946270 4947745 4941435 4947623 4944966 ...
> plot(deaths.df.rp.bag$Easting,deaths.df.rp.bag$Northing)
> deaths.df.rp.bag <- na.omit(deaths.df.rp.bag)
>
> library(spatstat)
> deaths.chull <- convexhull.xy(x=deaths.df.rp.bag$Easting,y=deaths.df.rp.bag$Northing)
> plot(deaths.chull)
> deaths.ppp <- ppp(x=deaths.df.rp.bag$Easting,y=deaths.df.rp.bag$Northing,window=deaths.chull,
+                   marks=deaths.df.rp.bag[,c(3,8:17)])
Warning message:
In ppp(x = deaths.df.rp.bag$Easting, y = deaths.df.rp.bag$Northing,  :
  data contain duplicated points
> summary(deaths.ppp)
Marked planar point pattern: 3350 points
Average intensity 3.47e-05 points per square unit

*Pattern contains duplicated points*

Coordinates are given to 1 decimal places
i.e. rounded to the nearest multiple of 0.1 units

Mark variables:  Type, Coalition.forces.wounded, Coalition.forces.killed, Iraq.forces.wounded,
Iraq.forces.killed, Civilian.wia, Civilian.kia, Enemy.wia, Enemy.kia, Enemy.detained, Total.deaths
Summary:
          Type      Coalition.forces.wounded Coalition.forces.killed Iraq.forces.wounded
Iraq.forces.killed  Civilian.wia
 Criminal Event  :1816   Min.   : 0.0000          Min.   :0.00000         Min.   : 0.0000     Min.   :
0.0000    Min.   :  0.00
 Explosive Hazard: 611   1st Qu.: 0.0000          1st Qu.:0.00000         1st Qu.: 0.0000     1st Qu.:
0.0000    1st Qu.:  0.00
 Enemy Action    : 592   Median : 0.0000          Median :0.00000         Median : 0.0000     Median :
0.0000    Median :  0.00
 Friendly Action : 266   Mean   : 0.1173          Mean   :0.04806         Mean   : 0.2179     Mean   :
0.1985    Mean   :  1.88
 Other           :  41   3rd Qu.: 0.0000          3rd Qu.:0.00000         3rd Qu.: 0.0000     3rd Qu.:
0.0000    3rd Qu.:  0.00
 Non-Combat Event:  18   Max.   :45.0000          Max.   :7.00000         Max.   :59.0000     Max.
:28.0000    Max.   :247.00
 (Other)         :   6
  Civilian.kia       Enemy.wia           Enemy.kia       Enemy.detained      Total.deaths
 Min.   :  0.000   Min.   :  0.00000   Min.   : 0.0000   Min.   : 0.00000   Min.   :  1.000
 1st Qu.:  0.000   1st Qu.:  0.00000   1st Qu.: 0.0000   1st Qu.: 0.00000   1st Qu.:  1.000
 Median :  1.000   Median :  0.00000   Median : 0.0000   Median : 0.00000   Median :  1.000
 Mean   :  1.566   Mean   :  0.09343   Mean   : 0.5101   Mean   : 0.07313   Mean   :  2.323
 3rd Qu.:  1.000   3rd Qu.:  0.00000   3rd Qu.: 0.0000   3rd Qu.: 0.00000   3rd Qu.:  2.000
 Max.   :181.000   Max.   :194.00000   Max.   :70.0000   Max.   :22.00000   Max.   :181.000
```

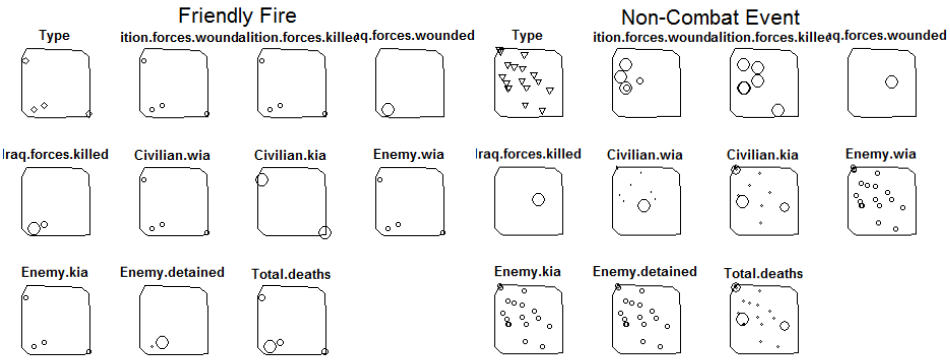
```
Window: polygonal boundary
single connected closed polygon with 16 vertices
enclosing rectangle: [10000045, 10009992] x [4940001, 4949997] units
Window area =  96440600 square units
```

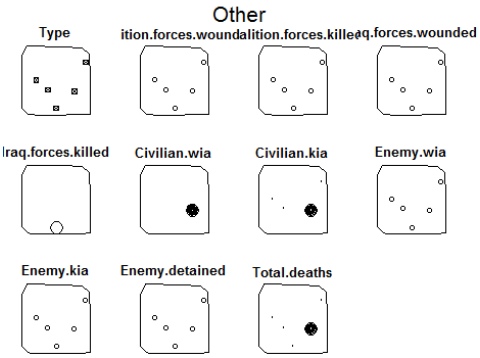
plot(deaths.ppp)
plot(split(deaths.ppp))



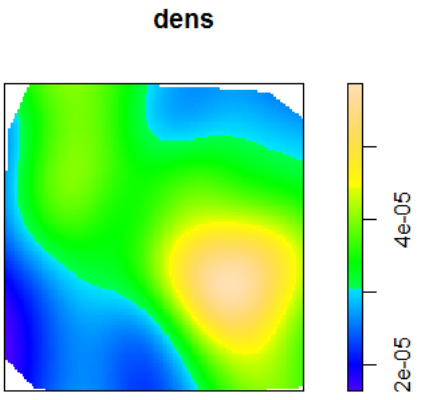


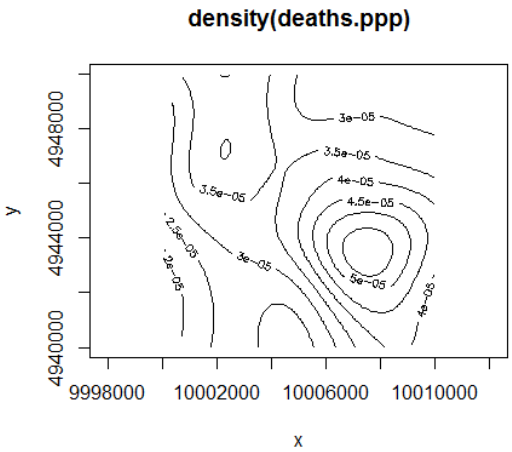




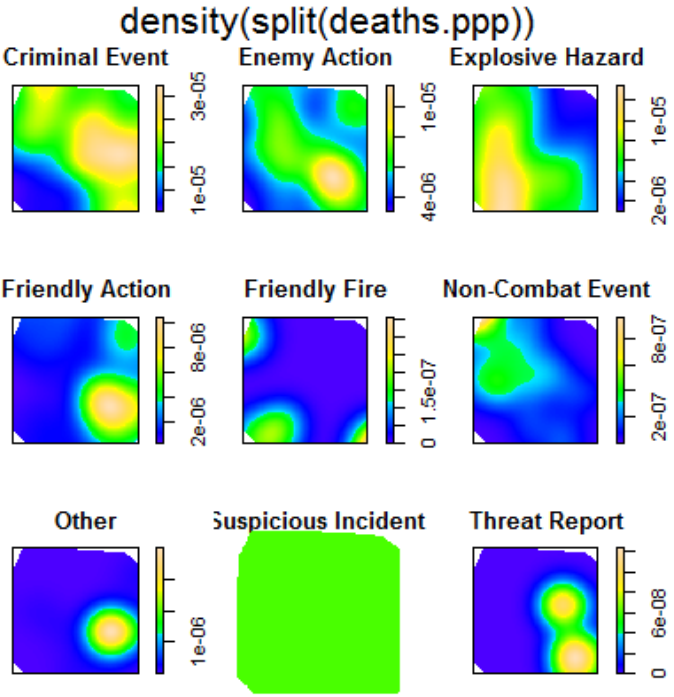


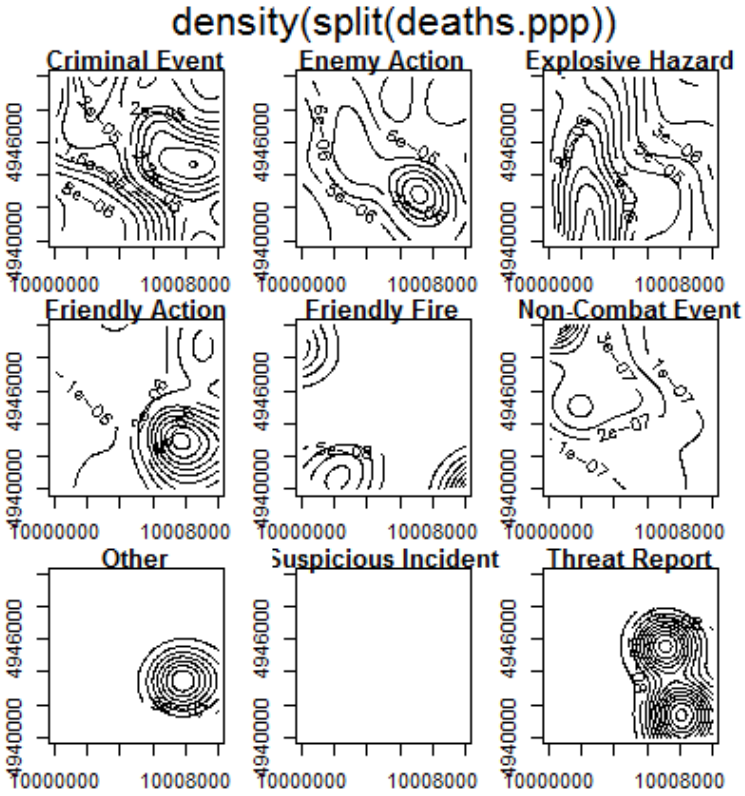

```
dens <- density(deaths.ppp)
plot(dens)
contour(density(deaths.ppp))
```



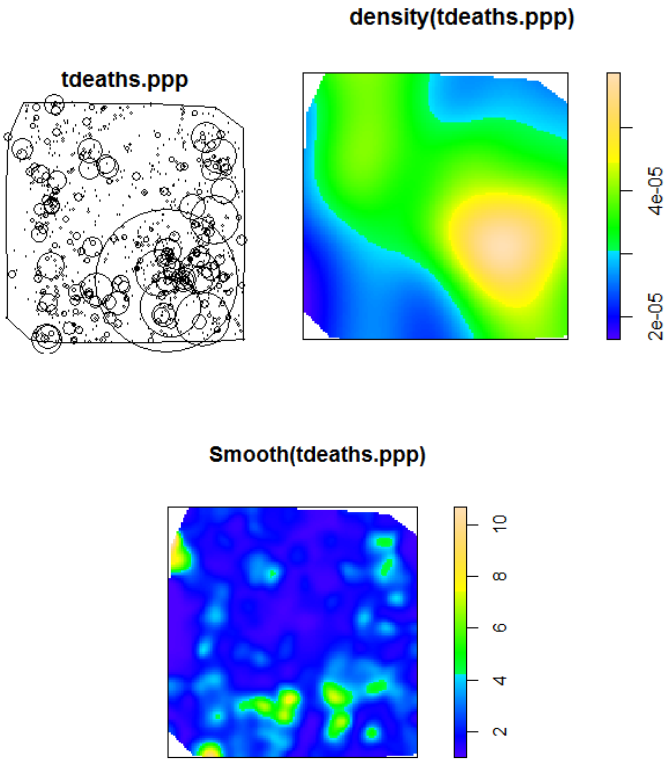


```
plot(density(split(deaths.ppp)))
contour(density(split(deaths.ppp)))
```

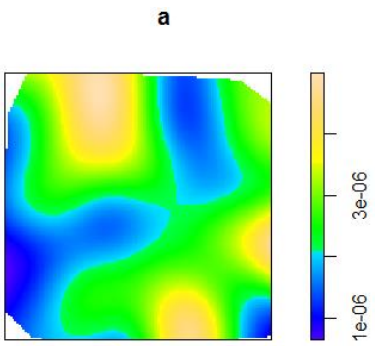




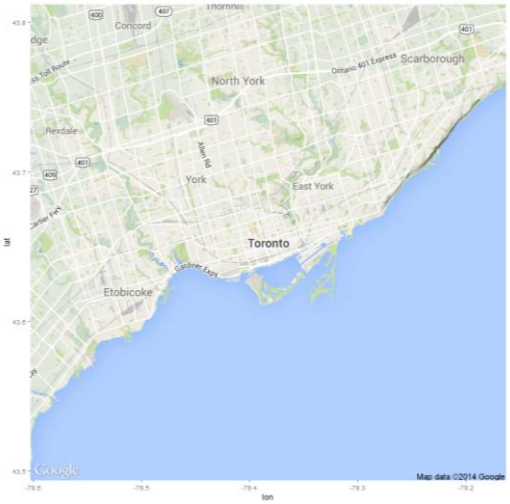
```
tdeaths.ppp <- ppp(x=deaths.df.rp.bag$Easting,y=deaths.df.rp.bag$Northing,window=deaths.chull,
          marks=deaths.df.rp.bag[,c(17)])
plot(tdeaths.ppp,maxsize=3000)
plot(density(tdeaths.ppp))
plot(Smooth(tdeaths.ppp))
```




```
points <- ppp(x=deaths.df.rp.bag$Easting,y=deaths.df.rp.bag$Northing,window=deaths.chull,
          marks=deaths.df.rp.bag[,c(17)])
plot(points)
plot(density(points))
a <- density(points,weights=deaths.df.rp.bag$Enemy.detained)

plot(a)
```



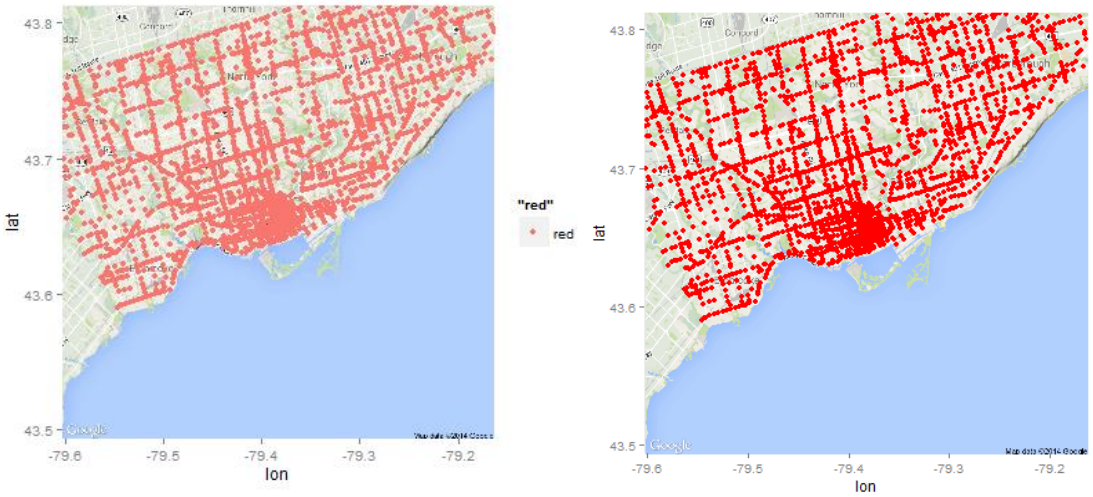
```
# Example 14
# heatmap of traffic signals Toronto

setwd("c:/R/Rdata")

library(ggmap)
library(ggplot2)

map <- get_map(location="Toronto",zoom=11)
Toronto <- ggmap(map,color="bw")
Toronto
```



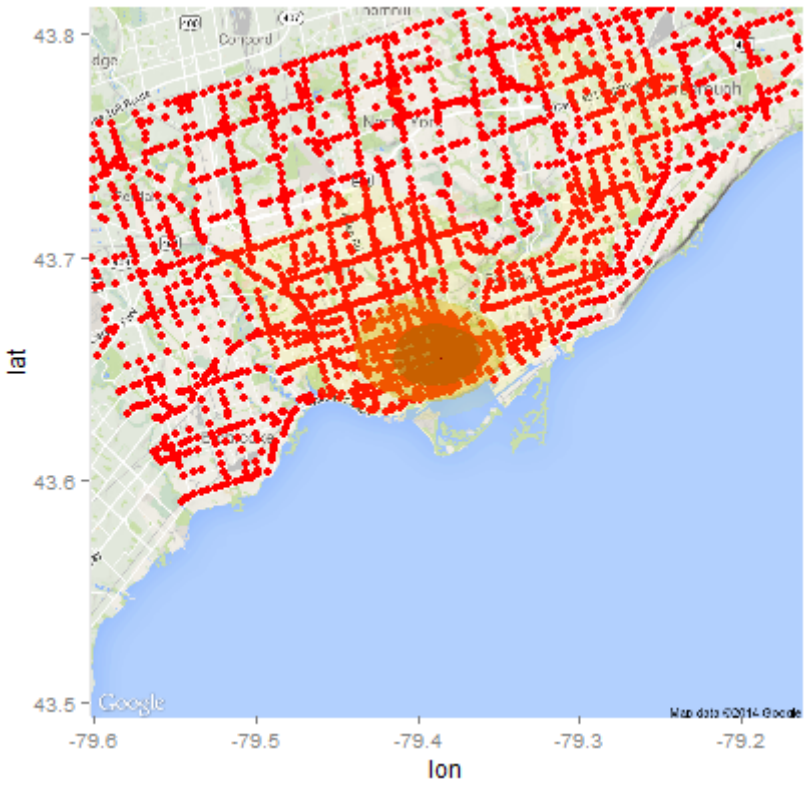

```
rawdata <- read.csv("traffic_signals.csv",header=T,sep=",")
data <- data.frame(as.numeric(rawdata$Longitude),as.numeric(rawdata$Latitude))
names(data) <- c("lon","lat")
data <- na.omit(data)
str(data)
head(data)
```

```
> str(data)
'data.frame':         2282 obs. of  2 variables:
 $ lon: num  -79.4 -79.4 -79.4 -79.4 -79.4 ...
 $ lat: num  43.6 43.7 43.7 43.7 43.7 ...
 - attr(*, "na.action")=Class 'omit'  Named int [1:518] 12 15 26 42 49 54 72 74 76 93 ...
  .. ..- attr(*, "names")= chr [1:518] "12" "15" "26" "42" ...
> head(data)
       lon      lat
1 -79.37145 43.64942
2 -79.37192 43.65046
3 -79.37236 43.65153
4 -79.37282 43.65272
5 -79.37324 43.65370
6 -79.37386 43.65536
```

```
p <- Toronto + geom_point(data=data,aes(x=lon,y=lat,col="red"))
p

p <- Toronto + geom_point(data=data,aes(x=lon,y=lat),col="red")
p
```



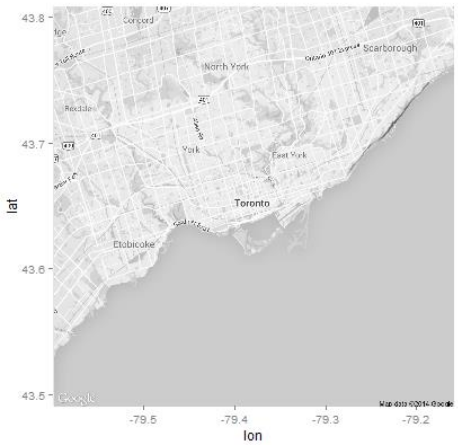

```
p <- p + stat_density2d(aes(x=lon,y=lat,fill=..level..,alpha=..level..),
                        size=2,bins=4,data=data,geom="polygon") +
                        scale_fill_gradient(low="yellow",high="darkred") +
                        theme(legend.position="none")
p
```



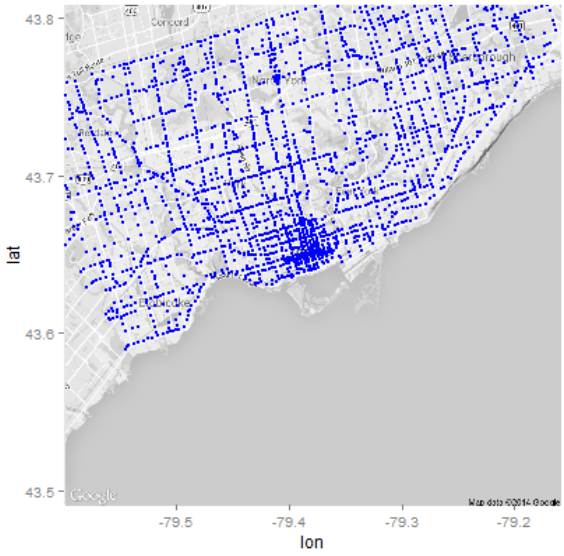
geocode(location="Toronto")

```
> geocode(location="Toronto")
Information from URL : http://maps.googleapis.com/maps/api/geocode/json?address=Toronto&sensor=false
Google Maps API Terms of Service : http://developers.google.com/maps/terms
        lon      lat
1 -79.38318 43.65323
```

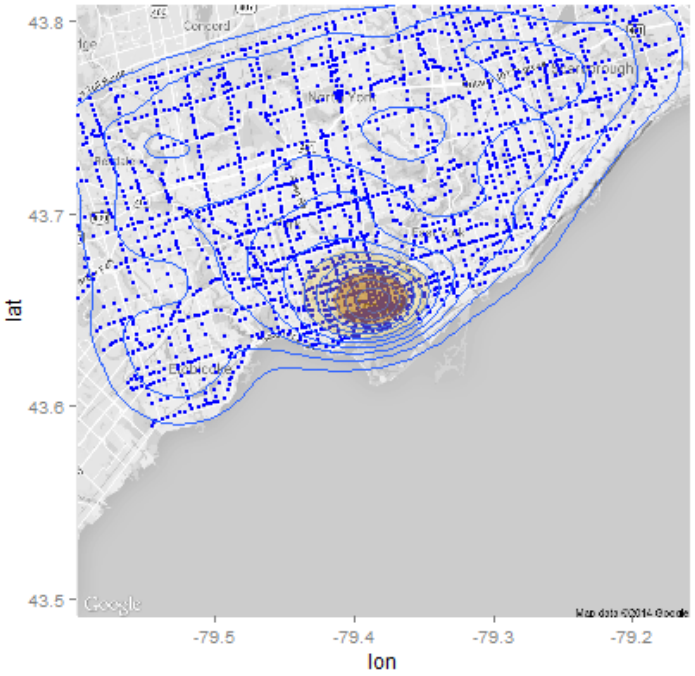
```
Toronto <- c(lon=-79.38,lat=43.65)
map <- get_map(Toronto,zoom=11,color="bw")
Toronto_map <- ggmap(map,extent="panel",maprange=FALSE)
Toronto_map
```




```
p <- Toronto_map + geom_point(data=data,aes(x=lon,y=lat),col="blue",size=.4)
p
```



```
p <- p + geom_density2d(data=data,aes(x=lon,y=lat)) +
 stat_density2d(aes(x=lon,y=lat,fill=..level..,alpha=..level..),
 size=2,bins=4,data=data,geom="polygon") +
 scale_fill_gradient(low="yellow",high="darkred") +
 scale_alpha(range=c(0.00,0.40),guide=FALSE) +
 theme(legend.position="none")
p
```



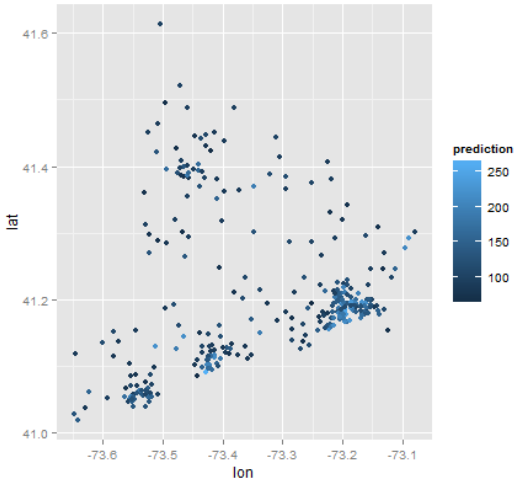
Example 15
stat_summary 2D plot of points with lat/lon-coordinates

setwd("c:/R/Rdata")
NYdata <- read.csv("NYsample.csv",header=T,sep=";")
str(NYdata)

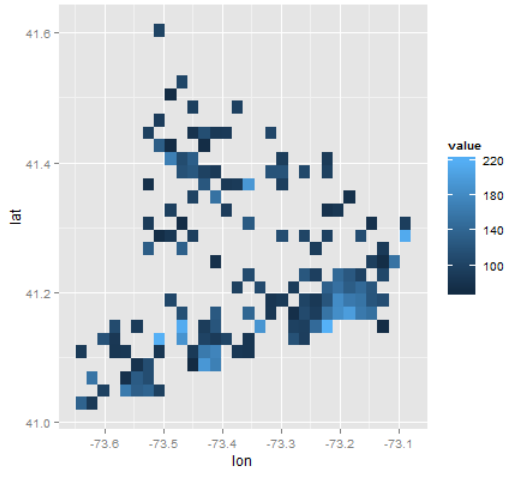
```
> str(NYdata)
'data.frame':         294 obs. of  4 variables:
 $ id        : num  9e+10 9e+10 9e+10 9e+10 9e+10 ...
 $ lat       : num  41.4 41.5 41.3 41.3 41.3 ...
 $ lon       : num  -73.4 -73.4 -73.5 -73.5 -73.5 ...
 $ prediction: num  90.1 97.5 70.8 95.7 94.9 ...
```

library(ggplot2)

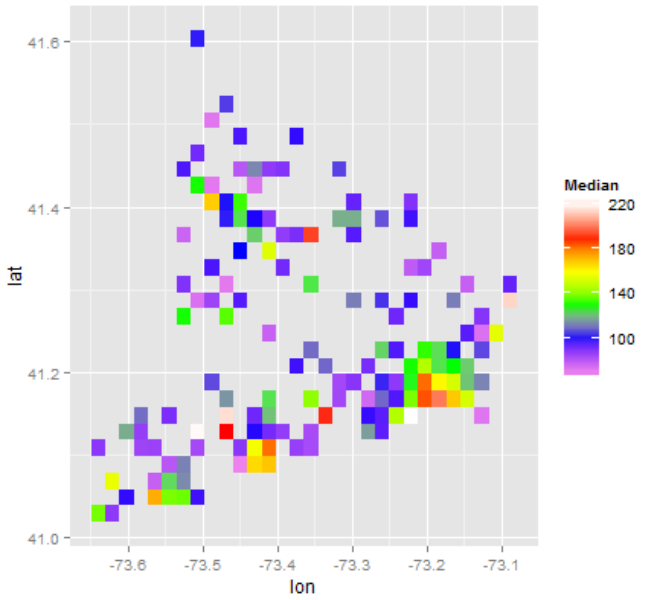
# basic plot
pred.plot <- ggplot(data=NYdata,aes(x=lon,y=lat,colour=prediction)) + geom_point()
pred.plot



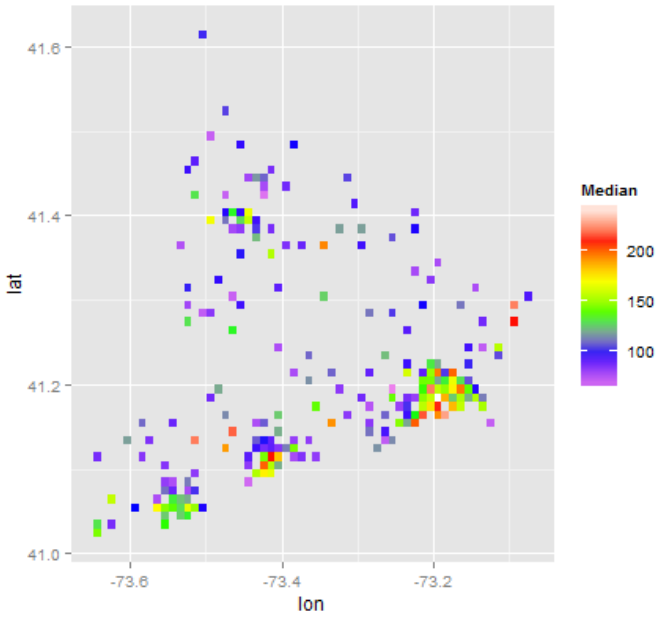
# binned data
# plot the mean in a 2D-region using stat_summary2D
pred.plot <- ggplot(data=NYdata,aes(x=lon,y=lat,z=prediction)) + stat_summary2d(fun=mean)
pred.plot



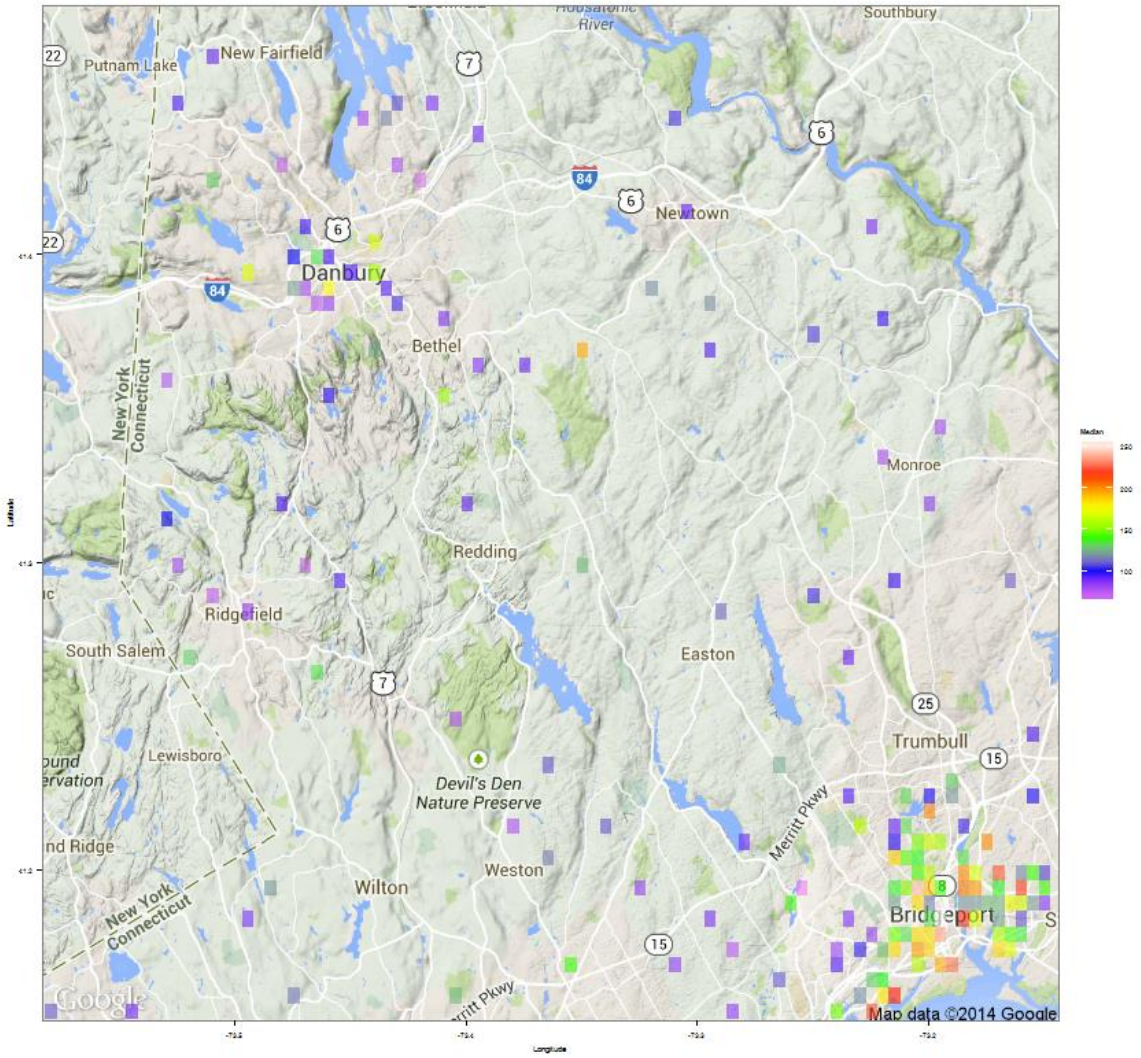
```
colormap <- c("Violet","Blue","Green","Yellow","Red","White")
pred.plot <- ggplot(data=NYdata,aes(x=lon,y=lat,z=prediction)) +
             stat_summary2d(fun=median) +
             scale_fill_gradientn(name="Median",colours=colormap,space="Lab")
pred.plot
```




```
pred.plot <- ggplot(data=NYdata,aes(x=lon,y=lat,z=prediction)) +
             stat_summary2d(fun=median,binwidth=c(0.010,0.010)) +
             scale_fill_gradientn(name="Median",colours=colormap,space="Lab")
pred.plot
```



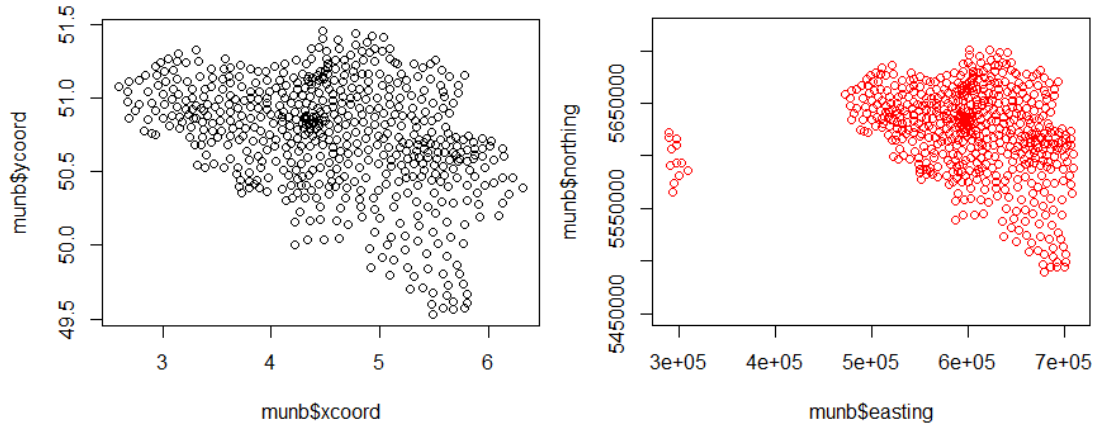
```
library(ggmap)

loc <- get_map(location=c(min(NYdata$lon),min(NYdata$lat),max(NYdata$lon),max(NYdata$lat)),
               source="google")
theme_set(theme_bw(base_size=6))
map <- ggmap(loc) %+% NYdata +
    aes(x=lon,y=lat,z=prediction) +
    stat_summary2d(fun=median,binwidth=c(0.005,0.005),alpha=0.6) +
    scale_fill_gradientn(name="Median",colours=colormap,space="Lab") +
    labs(x="Longitude",y="Latitude") +
    coord_map()
map
```



```
# Example 16
# convert lat-lon coordinates / UTM coordinates (easting-northing)

setwd("c:/R/Rdata")
municipalities <- read.csv("coord_gemeenten_Belgie.csv",header=T,sep=";")

# conversion from lat/lon to UTM with xls-file latlon to UTM and vice versa
# see c:\R\Rdata\UTMconversions.xls
munB <- subset(municipalities,select=c(XCOORD,YCOORD))
write.csv(munB,file="c:/temp/munb.csv")
# import of c:/R/Rdata/munb_latlon_utm (latlon coordinates converted to utm)
munb <- read.csv("munb_latlon_utm.csv",header=T,sep=";")
str(munb)
head(munb)
```

```
> str(munb)
'data.frame':         590 obs. of  4 variables:
 $ ycoord  : num  51.5 51.4 51.4 51.3 51.3 ...
 $ xcoord  : num  4.47 4.47 4.61 4.37 4.63 ...
 $ northing: num  6655207 5701311 5695928 5694965 5680415 ...
 $ easting : num  332705 602022 602222 611736 595620 ...
> head(munb)
    ycoord   xcoord northing  easting
1 51.45377 4.468343  6655207 332705.2
2 51.40534 4.469669  5701311 602022.3
3 51.39490 4.606091  5695928 602222.5
4 51.26705 4.370611  5694965 611736.2
5 51.33597 4.628302  5680415 595620.1
6 51.34243 4.440327  5688446 613426.8
```

```
plot(munb$xcoord,munb$ycoord)
plot(munb$easting,munb$northing,ylim=c(5450000,5720000),col="red")
```



Example 17 : stat density plots of Baltimore crime data
http://www.obscureanalytics.com/2012/12/07/visualizing-baltimore-with-r-and-ggplot2-crime-data
http://www.obscureanalytics.com/2012/12/10/visualizing-baltimore-2-vacant-property-and-some-more-crime

```
library(ggplot2)
library(foreign)
library(stringr)
library(lubridate)
library(plyr)
library(xtable)
library(scales)
library(RColorBrewer)
library(ggmap)
library(maptools)
library(sp)
library(rgdal)
library(spatstat)

setwd("c:/R/Rdata/Baltimore")

city_shp <- readOGR(".","baltcity_line")
class(city_shp)
summary(city_shp)
proj4string(city_shp)
# if we want to convert this shapefile to lat/lon :
# city_shp <- spTransform(city_shp,CRS("+proj=longlat +datum=WGS84"))
# we store the orginal projection of the shapefile :
origProj <- city_shp@proj4string
origProj
```

```
> city_shp <- readOGR(".","baltcity_line")
OGR data source with driver: ESRI Shapefile
Source: ".", layer: "baltcity_line"
with 1 features and 7 fields
Feature type: wkbLineString with 2 dimensions
> class(city_shp)
[1] "SpatialLinesDataFrame"
attr(,"package")
[1] "sp"
> summary(city_shp)
Object of class SpatialLinesDataFrame
Coordinates:
      min       max
x 1393953.1 1445550.6
y  557733.6  621406.8
Is projected: TRUE
proj4string :
[+proj=lcc +lat_1=38.3 +lat_2=39.45 +lat_0=37.66666666666666 +lon_0=-77 +x_0=399999.9999999999 +y_0=0
+datum=NAD83
+units=us-ft +no_defs +ellps=GRS80 +towgs84=0,0,0]
Data attributes:
       ID             AREA             PERIMETER        BOUNDARY_    BOUNDARY_I      LENGTH          Shape_Leng
 Min.   :0   Min.   :2.563e+09   Min.   :207127   Min.   :2   Min.   :0   Min.   :207127   Min.   :207127
 1st Qu.:0   1st Qu.:2.563e+09   1st Qu.:207127   1st Qu.:2   1st Qu.:0   1st Qu.:207127   1st Qu.:207127
 Median :0   Median :2.563e+09   Median :207127   Median :2   Median :0   Median :207127   Median :207127
 Mean   :0   Mean   :2.563e+09   Mean   :207127   Mean   :2   Mean   :0   Mean   :207127   Mean   :207127
 3rd Qu.:0   3rd Qu.:2.563e+09   3rd Qu.:207127   3rd Qu.:2   3rd Qu.:0   3rd Qu.:207127   3rd Qu.:207127
 Max.   :0   Max.   :2.563e+09   Max.   :207127   Max.   :2   Max.   :0   Max.   :207127   Max.   :207127
> proj4string(city_shp)
[1] "+proj=lcc +lat_1=38.3 +lat_2=39.45 +lat_0=37.66666666666666 +lon_0=-77 +x_0=399999.9999999999 +y_0=0
+datum=NAD83 +units=us-ft +no_defs +ellps=GRS80 +towgs84=0,0,0"
> # if we want to convert this shapefile to lat/lon :
> # city_shp <- spTransform(city_shp,CRS("+proj=longlat +datum=WGS84"))
> # we store the orginal projection of the shapefile :
> origProj <- city_shp@proj4string
> origProj
CRS arguments:
 +proj=lcc +lat_1=38.3 +lat_2=39.45 +lat_0=37.66666666666666 +lon_0=-77 +x_0=399999.9999999999 +y_0=0
+datum=NAD83
+units=us-ft +no_defs +ellps=GRS80 +towgs84=0,0,0
```

```
city_shp_df <- fortify(city_shp,region="LABEL")
str(city_shp_df)
```

```
> str(city_shp_df)
'data.frame':	8 obs. of  6 variables:
 $ long : num  1393953 1445298 1445551 1439944 1430304 ...
 $ lat  : num  621188 621407 562275 557734 561653 ...
 $ order: int  1 2 3 4 5 6 7 8
 $ piece: Factor w/ 1 level "1": 1 1 1 1 1 1 1 1
 $ group: Factor w/ 1 level "0.1": 1 1 1 1 1 1 1 1
 $ id   : chr  "0" "0" "0" "0" ...
```

```
# we use this data frame as the first layer
bound_plot <- ggplot(data=city_shp_df,aes(x=long,y=lat,group=group)) +
        geom_polygon(color="gray",fill="lightblue") +
        coord_equal() + theme_nothing()
bound_plot
```

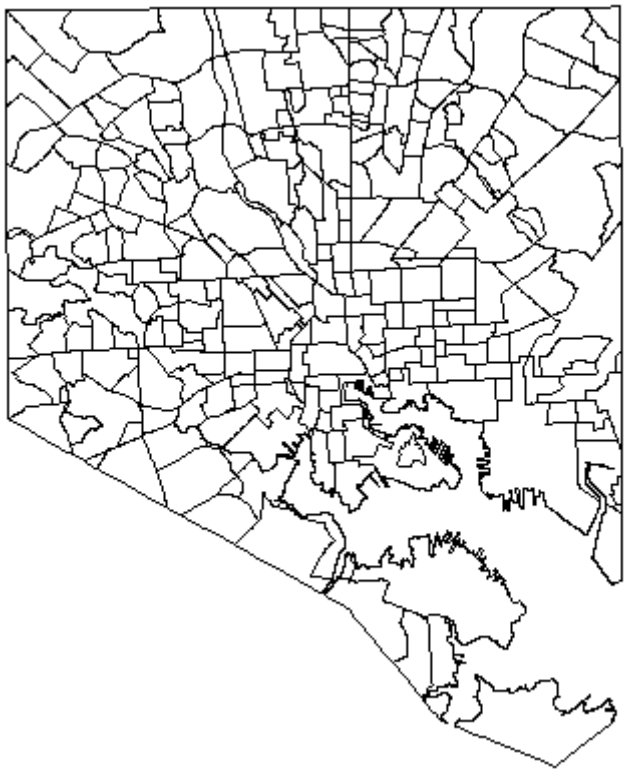
```
# neighborhoods
nbhds_shp <- readOGR(".","Neighborhoods_2010")
class(nbhds_shp)
summary(nbhds_shp)
str(nbhds_shp@data)
# we store the orginal projection of the shapefile :
origProj <- nbhds_shp@proj4string
origProj
```

```
> nbhds_shp <- readOGR(".","Neighborhoods_2010")
OGR data source with driver: ESRI Shapefile
Source: ".", layer: "Neighborhoods_2010"
with 278 features and 36 fields
Feature type: wkbPolygon with 2 dimensions
> class(nbhds_shp)
[1] "SpatialPolygonsDataFrame"
attr(,"package")
[1] "sp"
> summary(nbhds_shp)
Object of class SpatialPolygonsDataFrame
Coordinates:
        min       max
x 1393926.8 1445503.0
y  557733.6  621406.8
Is projected: TRUE
proj4string :
[+proj=lcc +lat_1=38.3 +lat_2=39.45 +lat_0=37.66666666666666 +lon_0=-77 +x_0=399999.9999999999 +y_0=0
+datum=NAD83
+units=us-ft +no_defs +ellps=GRS80 +towgs84=0,0,0]
Data attributes:
                Name       Population        White            Blk_AfAm         AmInd_AkNa          Asian
NatHaw_Pac
```

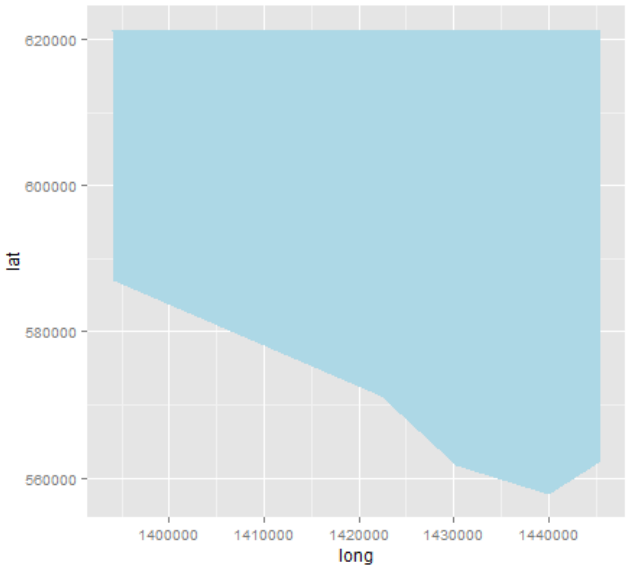
```
 Abell            :  1   Min.   :    0   Min.   :    0.0   Min.   :    0.0   Min.   :  0.000   Min.   :
0.00   Min.   : 0.0000
 Allendale        :  1   1st Qu.:  737   1st Qu.:   23.5   1st Qu.:  225.5   1st Qu.:  1.000   1st Qu.:
3.00   1st Qu.: 0.0000
 Arcadia          :  1   Median : 1568   Median :  144.0   Median :  964.5   Median :  5.000   Median :
10.50   Median : 0.0000
 Arlington        :  1   Mean   : 2231   Mean   :  660.3   Mean   : 1421.8   Mean   :  8.162   Mean   :
52.31   Mean   : 0.9856
 Armistead Gardens:  1   3rd Qu.: 2884   3rd Qu.:  625.2   3rd Qu.: 1942.2   3rd Qu.: 10.000   3rd Qu.:
41.25   3rd Qu.: 1.0000
 Ashburton        :  1   Max.   :17694   Max.   :10811.0   Max.   :14958.0   Max.   :108.000   Max.
:1883.00   Max.   :25.0000
 (Other)          :272
   Other_Race       TwoOrMore         Hisp_Lat            Male            Female           AGE0_4
AGE5_11
 Min.   :  0.00   Min.   :  0.00   Min.   :   0.00   Min.   :   0.0   Min.   :   0.0   Min.   :   0.00
Min.   :   0.0
 1st Qu.:  2.00   1st Qu.: 12.25   1st Qu.:  12.00   1st Qu.: 334.5   1st Qu.: 397.8   1st Qu.:  42.16
1st Qu.:  48.0
 Median :  9.00   Median : 27.00   Median :  26.00   Median : 719.0   Median : 857.0   Median : 101.50
Median : 118.5
 Mean   : 40.63   Mean   : 46.58   Mean   :  93.33   Mean   :1049.9   Mean   :1181.0   Mean   : 147.90
Mean   : 178.7
 3rd Qu.: 23.00   3rd Qu.: 54.75   3rd Qu.:  77.00   3rd Qu.:1343.5   3rd Qu.:1576.2   3rd Qu.: 185.50
3rd Qu.: 232.8
 Max.   :777.00   Max.   :453.00   Max.   :1624.00   Max.   :8056.0   Max.   :9638.0   Max.   :1383.00
Max.   :1734.0

    AGE12_14         AGE15_17         AGE18_24         AGE25_34         AGE35_44         AGE45_64
AGE65ovr
 Min.   :  0.00   Min.   :  0.0   Min.   :   0.00   Min.   :   0.00   Min.   :   0.0   Min.   :   0.0
Min.   :   0.00
 1st Qu.: 17.25   1st Qu.: 19.0   1st Qu.:  74.25   1st Qu.:  92.75   1st Qu.:  90.0   1st Qu.: 191.5   1st
Qu.:  77.63
 Median : 45.00   Median : 58.0   Median : 166.00   Median : 216.50   Median : 184.5   Median : 418.0
Median : 184.00
 Mean   : 72.15   Mean   : 81.3   Mean   : 280.75   Mean   : 372.16   Mean   : 275.1   Mean   : 561.7
Mean   : 261.17
 3rd Qu.: 96.00   3rd Qu.:106.5   3rd Qu.: 316.50   3rd Qu.: 428.75   3rd Qu.: 348.8   3rd Qu.: 756.2   3rd
Qu.: 330.75
 Max.   :794.00   Max.   :873.0   Max.   :4562.00   Max.   :4835.00   Max.   :2269.0   Max.   :4675.0
Max.   :1687.00

    Families         Married          Married18          MaleHH          MaleHH18         FemaleHH
FemaleHH18
 Min.   :   0.0   Min.   :   0.00   Min.   :  0.00   Min.   :  0.00   Min.   :  0.00   Min.   :   0.0
Min.   :   0.00
 1st Qu.: 166.2   1st Qu.:  67.75   1st Qu.: 19.39   1st Qu.: 12.00   1st Qu.:  5.00   1st Qu.:  44.0   1st
Qu.:  19.25
 Median : 350.0   Median : 137.00   Median : 44.50   Median : 37.00   Median : 13.00   Median : 141.0
Median :  66.00
 Mean   : 481.7   Mean   : 216.63   Mean   : 75.30   Mean   : 50.88   Mean   : 19.46   Mean   : 214.2
Mean   : 105.92
 3rd Qu.: 625.8   3rd Qu.: 251.75   3rd Qu.: 86.50   3rd Qu.: 64.75   3rd Qu.: 25.00   3rd Qu.: 294.0   3rd
Qu.: 130.75
 Max.   :4175.0   Max.   :1761.00   Max.   :679.00   Max.   :432.00   Max.   :211.00   Max.   :2318.0
Max.   :1191.00

    Housing          Occupied         Occ_Own          Occ_Rent         Vacant          Vac_Rent
Vac_Sale
 Min.   :   0.0   Min.   :   0.0   Min.   :   0.0   Min.   :   0.0   Min.   :   0.0   Min.   :  0.00   Min.
:  0.00
 1st Qu.: 325.5   1st Qu.: 293.2   1st Qu.: 135.5   1st Qu.: 102.0   1st Qu.:  31.0   1st Qu.:  9.00   1st
Qu.:  3.00
 Median : 741.0   Median : 617.0   Median : 285.5   Median : 288.5   Median :  94.0   Median : 31.00
Median :  9.00
 Mean   :1066.1   Mean   : 898.1   Mean   : 428.0   Mean   : 470.0   Mean   : 168.1   Mean   : 56.63   Mean
: 18.71
 3rd Qu.:1315.8   3rd Qu.:1121.2   3rd Qu.: 532.0   3rd Qu.: 574.8   3rd Qu.: 213.0   3rd Qu.: 75.00   3rd
Qu.: 22.00
 Max.   :7894.0   Max.   :7137.0   Max.   :4107.0   Max.   :4167.0   Max.   :1069.0   Max.   :450.00   Max.
:246.00

   Vac_Other
 Min.   :  0.00
 1st Qu.: 11.25
 Median : 43.50
 Mean   : 92.71
 3rd Qu.:110.00
 Max.   :853.00

> str(nbhds_shp@data)
'data.frame':         278 obs. of  36 variables:
 $ Name      : Factor w/ 278 levels "Abell","Allendale",..: 1 2 3 4 5 6 7 197 8 9 ...
 $ Population: num  889 3554 1235 2598 3458 ...
 $ White     : num  606 18 623 33 2698 ...
 $ Blk_AfAm  : num  213 3497 537 2496 108 ...
 $ AmInd_AkNa: num  3 8 4 3 51 6 63 108 10 6 ...
 $ Asian     : num  33 6 12 9 14 4 75 143 23 34 ...
 $ NatHaw_Pac: num  1 0 0 0 8 0 11 2 0 0 ...
 $ Other_Race: num  4 5 10 10 413 15 693 774 35 12 ...
 $ TwoOrMore : num  29 20 49 47 166 31 138 207 47 16 ...
 $ Hisp_Lat  : num  30 21 31 17 841 ...
 $ Male      : num  424 1536 592 1219 1621 ...
 $ Female    : num  465 2018 643 1379 1837 ...
 $ AGE0_4    : num  55 179 101 148 266 106 253 506 127 14 ...
 $ AGE5_11   : num  43 315 85 237 330 178 203 443 129 19 ...
 $ AGE12_14  : num  5 136 40 92 113 79 85 150 42 7 ...
 $ AGE15_17  : num  10 181 55 114 125 103 95 149 57 10 ...
```

```
 $ AGE18_24  : num  118 317 116 231 272 192 358 665 255 82 ...
 $ AGE25_34  : num  254 383 188 297 496 ...
 $ AGE35_44  : num  149 315 164 305 438 250 413 851 280 62 ...
 $ AGE45_64  : num  186 1039 380 775 929 ...
 $ AGE65ovr  : num  69 689 106 399 489 607 227 307 183 26 ...
 $ Families  : num  159 874 305 585 877 ...
 $ Married   : num  105 253 194 215 431 326 194 625 119 49 ...
 $ Married18 : num  41 62 79 63 164 99 90 250 24 14 ...
 $ MaleHH    : num  12 111 23 76 115 65 108 157 52 7 ...
 $ MaleHH18  : num  4 34 9 28 47 21 35 65 10 5 ...
 $ FemaleHH  : num  42 510 88 294 331 234 212 370 208 13 ...
 $ FemaleHH18: num  19 193 40 130 160 78 119 195 97 5 ...
 $ Housing   : num  515 1608 510 1312 1543 ...
 $ Occupied  : num  440 1433 462 1079 1459 ...
 $ Occ_Own   : num  248 818 356 485 981 ...
 $ Occ_Rent  : num  192 615 106 594 478 310 574 910 732 111 ...
 $ Vacant    : num  75 175 48 233 84 105 272 474 535 36 ...
 $ Vac_Rent  : num  49 99 14 64 26 18 98 187 127 11 ...
 $ Vac_Sale  : num  4 20 9 24 17 14 45 75 33 3 ...
 $ Vac_Other : num  22 56 25 145 41 73 129 212 375 22 ...
> # we store the orginal projection of the shapefile :
> origProj <- nbhds_shp@proj4string
> origProj
CRS arguments:
 +proj=lcc +lat_1=38.3 +lat_2=39.45 +lat_0=37.66666666666666 +lon_0=-77 +x_0=399999.9999999999 +y_0=0
+datum=NAD83
+units=us-ft +no_defs +ellps=GRS80 +towgs84=0,0,0
```

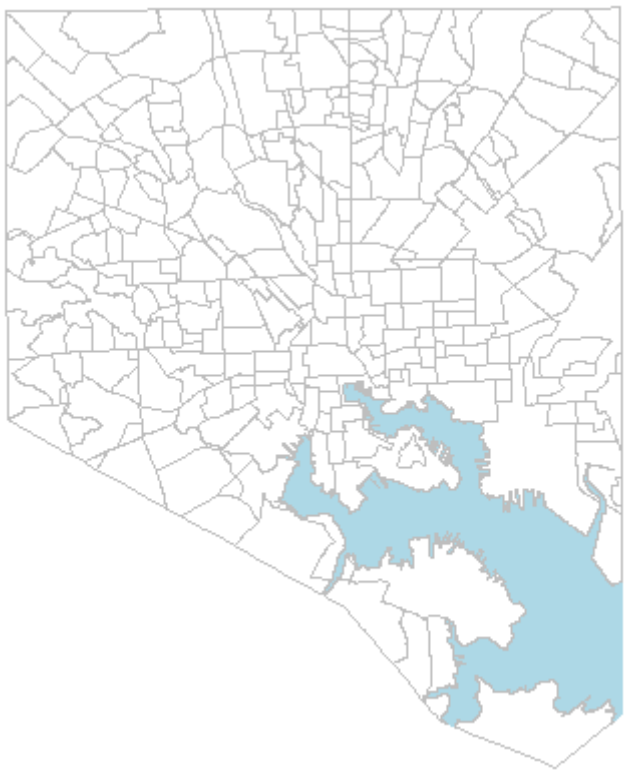
```
# convert to data frame with fortify
nbhds_pl_df <- fortify(nbhds_shp,region="Name")
plot_nbhds_pl_df <- ggplot(data=nbhds_pl_df,aes(x=long,y=lat,group=group)) +
                                    geom_polygon(color="black",fill="white") +
                                    coord_equal() + theme_nothing()
plot_nbhds_pl_df
```



```
plot <- ggplot(data=city_shp_df,aes(x=long,y=lat,group=group)) + geom_polygon(fill="lightblue")
plot
```




```
neighborhoods <- plot +
geom_polygon(data=nbhds_pl_df,aes(x=long,y=lat,grou=group),color="gray",fill="white") +
                    coord_equal() + theme_nothing()
neighborhoods
```



```
# crime data
crimeData <- read.csv("BPD_Part_1_Victim_Based_Crime_Data.csv",header=T,sep=",")
str(crimeData)
table(crimeData$description)
```

```
> str(crimeData)
'data.frame':	248574 obs. of  10 variables:
 $ crimeDate   : Factor w/ 1865 levels "01/01/2009","01/01/2010",..: 7 7 7 7 7 7 7 7 7 7 ...
 $ crimeTime   : Factor w/ 3785 levels "00:00:00","00:00:11",..: 790 911 1053 1081 1115 1115 1115 1115 1144
1375 ...
 $ crimeCode   : Factor w/ 81 levels "1F","1K","1O",..: 1 59 55 48 55 44 55 44 43 43 ...
 $ location    : Factor w/ 21375 levels "","0 6015 FALLS",..: 2104 4742 16259 9264 9838 20468 4842 20468
15327 4077 ...
 $ description : Factor w/ 14 levels "AGG. ASSAULT",..: 6 7 7 4 7 5 7 5 5 5 ...
 $ weapon      : Factor w/ 5 levels "","FIREARM","HANDS",..: 2 1 1 1 1 1 1 1 1 1 ...
 $ post        : int  315 321 833 223 212 311 426 311 526 731 ...
 $ district    : Factor w/ 10 levels "","CENTRAL","EASTERN",..: 3 3 9 7 7 3 4 3 5 10 ...
 $ neighborhood: Factor w/ 278 levels "","Abell","Allendale",..: 183 26 12 197 68 70 204 70 266 230 ...
 $ Location.1  : Factor w/ 89247 levels "","(37.577260000000003, -81.52919)",..: 30935 47682 9775 27057
30259 51732 81689 51732 73759 41739 ...
> table(crimeData$description)

        AGG. ASSAULT                ARSON           AUTO THEFT              BURGLARY        COMMON ASSAULT
HOMICIDE
               25991                1503                19602                 40065                 48573
1141
             LARCENY    LARCENY FROM AUTO                RAPE ROBBERY - CARJACKING ROBBERY - COMMERCIAL
ROBBERY - RESIDENCE
               52516                35825                1382                   876                  2951
2682
    ROBBERY - STREET             SHOOTING
               13410                2057
```

```
crimeData <- na.omit(crimeData)

# the coordinates of the crime points are given as text, so we need to convert
# the data in crimeData$Location.1
latlng <- str_replace(str_replace(crimeData$Location.1,'\\(',''),')','')
latlng <- str_split(latlng,', ')
latlng_df <- ldply(latlng)
str(latlng_df)
head(latlng_df)
crimeData$lat <- as.numeric(latlng_df[,1])
crimeData$long <- as.numeric(latlng_df[,2])
str(crimeData)
head(crimeData)
```

```
> str(latlng_df)
'data.frame':	245374 obs. of  2 variables:
 $ V1: chr  "39.294960000000003" "39.310090000000002" "39.277119999999996" "39.292200000000001" ...
 $ V2: chr  "-76.603170000000006" "-76.590249999999997" "-76.695580000000007" "-76.576080000000005" ...
> head(latlng_df)
                V1                  V2
1 39.294960000000003 -76.603170000000006
2 39.310090000000002 -76.590249999999997
3 39.277119999999996 -76.695580000000007
4 39.292200000000001 -76.576080000000005
5 39.294510000000002 -76.598939999999999
6 39.314610000000002             -76.60651
> crimeData$lat <- as.numeric(latlng_df[,1])
> crimeData$long <- as.numeric(latlng_df[,2])
> str(crimeData)
'data.frame':	245374 obs. of  12 variables:
 $ crimeDate   : Factor w/ 1865 levels "01/01/2009","01/01/2010",..: 7 7 7 7 7 7 7 7 7 7 ...
 $ crimeTime   : Factor w/ 3785 levels "00:00:00","00:00:11",..: 790 911 1053 1081 1115 1115 1115 1115 1144
1375 ...
 $ crimeCode   : Factor w/ 81 levels "1F","1K","1O",..: 1 59 55 48 55 44 55 44 43 43 ...
 $ location    : Factor w/ 21375 levels "","0 6015 FALLS",..: 2104 4742 16259 9264 9838 20468 4842 20468
15327 4077 ...
 $ description : Factor w/ 14 levels "AGG. ASSAULT",..: 6 7 7 4 7 5 7 5 5 5 ...
 $ weapon      : Factor w/ 5 levels "","FIREARM","HANDS",..: 2 1 1 1 1 1 1 1 1 1 ...
 $ post        : int  315 321 833 223 212 311 426 311 526 731 ...
 $ district    : Factor w/ 10 levels "","CENTRAL","EASTERN",..: 3 3 9 7 7 3 4 3 5 10 ...
 $ neighborhood: Factor w/ 278 levels "","Abell","Allendale",..: 183 26 12 197 68 70 204 70 266 230 ...
 $ Location.1  : Factor w/ 89247 levels "","(37.577260000000003, -81.52919)",..: 30935 47682 9775 27057
30259 51732 81689 51732 73759 41739 ...
 $ lat         : num  39.3 39.3 39.3 39.3 39.3 ...
 $ long        : num  -76.6 -76.6 -76.7 -76.6 -76.6 ...
 - attr(*, "na.action")=Class 'omit'  Named int [1:3200] 42 57 289 313 327 349 611 649 760 828 ...
  .. ..- attr(*, "names")= chr [1:3200] "42" "57" "289" "313" ...
```

```
> head(crimeData)
   crimeDate crimeTime crimeCode             location    description  weapon post     district
neighborhood
1 01/02/2009      0450        1F      1100 ORLEANS ST       HOMICIDE FIREARM  315      EASTERN
Oldtown
2 01/02/2009  06:00:00        6J 1700 N WASHINGTON ST         LARCENY          321      EASTERN
Broadway East
3 01/02/2009  07:30:00        6E       500 COLLEEN RD         LARCENY          833 SOUTHWESTERN
Beechfield
4 01/02/2009  07:45:00        5D  2900 E BALTIMORE ST       BURGLARY          223 SOUTHEASTERN Patterson
Park Neighborhood
5 01/02/2009  08:00:00        6E        300 N EDEN ST         LARCENY          212 SOUTHEASTERN
Dunbar-Broadway
6 01/02/2009  08:00:00        4F        800 E 22ND ST COMMON ASSAULT          311      EASTERN       East
Baltimore Midway
                            Location.1      lat      long
1 (39.294960000000003, -76.603170000000006) 39.29496 -76.60317
2 (39.310090000000002, -76.590249999999997) 39.31009 -76.59025
3 (39.277119999999996, -76.695580000000007) 39.27712 -76.69558
4 (39.292200000000001, -76.576080000000005) 39.29220 -76.57608
5 (39.294510000000002, -76.598939999999999) 39.29451 -76.59894
6          (39.314610000000002, -76.60651) 39.31461 -76.60651
```

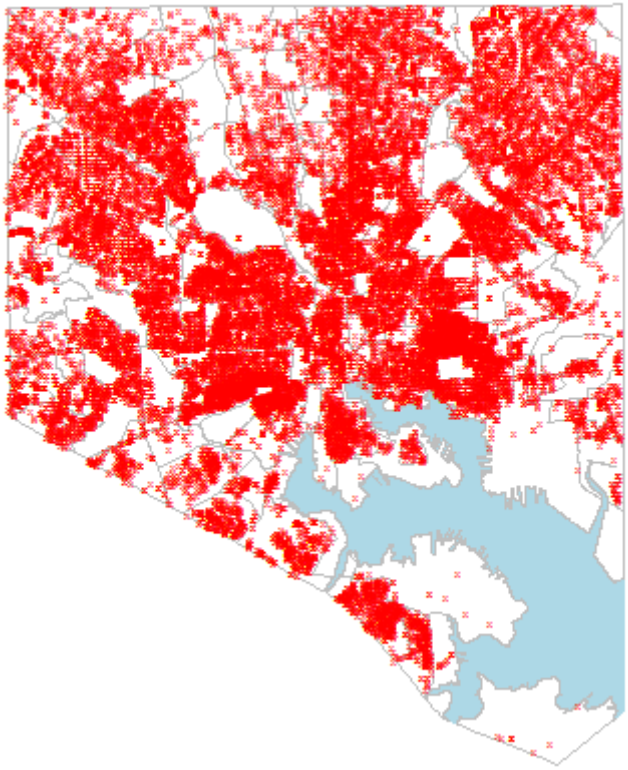
```
# convert lat/long coordinates to the original projection
latlng_df2 <- crimeData[,c("long","lat")]
latlng_spdf <- SpatialPoints(latlng_df2,proj4string=CRS("+proj=longlat +datum=WGS84"))
latlng_spdf <- spTransform(latlng_spdf,origProj)
proj4string(latlng_spdf)
str(latlng_spdf)
latlng_spdf_coords <- coordinates(latlng_spdf)
str(latlng_spdf_coords)
crimeData$long <- latlng_spdf_coords[,1]
crimeData$lat <- latlng_spdf_coords[,2]
str(crimeData)
```

```
> proj4string(latlng_spdf)
[1] "+proj=lcc +lat_1=38.3 +lat_2=39.45 +lat_0=37.66666666666666 +lon_0=-77 +x_0=399999.9999999999 +y_0=0
+datum=NAD83 +units=us-ft +no_defs +ellps=GRS80 +towgs84=0,0,0"
> str(latlng_spdf)
Formal class 'SpatialPoints' [package "sp"] with 3 slots
  ..@ coords     : num [1:245374, 1:2] 1424642 1428274 1398511 1432314 1425840 ...
  .. ..- attr(*, "dimnames")=List of 2
  .. .. ..$ : NULL
  .. .. ..$ : chr [1:2] "long" "lat"
  ..@ bbox       : num [1:2, 1:2] 1393970 558882 1445474 621385
  .. ..- attr(*, "dimnames")=List of 2
  .. .. ..$ : chr [1:2] "long" "lat"
  .. .. ..$ : chr [1:2] "min" "max"
  ..@ proj4string:Formal class 'CRS' [package "sp"] with 1 slots
  .. .. ..@ projargs: chr "+proj=lcc +lat_1=38.3 +lat_2=39.45 +lat_0=37.66666666666666 +lon_0=-77
+x_0=399999.9999999999 +y_0=0 +datum=NAD83 +units=us-ft "| __truncated__
> latlng_spdf_coords <- coordinates(latlng_spdf)
> str(latlng_spdf_coords)
 num [1:245374, 1:2] 1424642 1428274 1398511 1432314 1425840 ...
 - attr(*, "dimnames")=List of 2
  ..$ : NULL
  ..$ : chr [1:2] "long" "lat"
> crimeData$long <- latlng_spdf_coords[,1]
> crimeData$lat <- latlng_spdf_coords[,2]
> str(crimeData)
'data.frame':         245374 obs. of  12 variables:
 $ crimeDate   : Factor w/ 1865 levels "01/01/2009","01/01/2010",..: 7 7 7 7 7 7 7 7 7 7 ...
 $ crimeTime   : Factor w/ 3785 levels "00:00:00","00:00:11",..: 790 911 1053 1081 1115 1115 1115 1115 1144
1375 ...
 $ crimeCode   : Factor w/ 81 levels "1F","1K","1O",..: 1 59 55 48 55 44 55 44 43 43 ...
 $ location    : Factor w/ 21375 levels "","0 6015 FALLS",..: 2104 4742 16259 9264 9838 20468 4842 20468
15327 4077 ...
 $ description : Factor w/ 14 levels "AGG. ASSAULT",..: 6 7 7 4 7 5 7 5 5 5 ...
 $ weapon      : Factor w/ 5 levels "","FIREARM","HANDS",..: 2 1 1 1 1 1 1 1 1 1 ...
 $ post        : int  315 321 833 223 212 311 426 311 526 731 ...
 $ district    : Factor w/ 10 levels "","CENTRAL","EASTERN",..: 3 3 9 7 7 3 4 3 5 10 ...
 $ neighborhood: Factor w/ 278 levels "","Abell","Allendale",..: 183 26 12 197 68 70 204 70 266 230 ...
 $ Location.1  : Factor w/ 89247 levels "","(37.577260000000003, -81.52919)",..: 30935 47682 9775 27057
30259 51732 81689 51732 73759 41739 ...
 $ lat         : num  593258 598785 586659 592287 593099 ...
 $ long        : num  1424642 1428274 1398511 1432314 1425840 ...
 - attr(*, "na.action")=Class 'omit'  Named int [1:3200] 42 57 289 313 327 349 611 649 760 828 ...
  .. ..- attr(*, "names")= chr [1:3200] "42" "57" "289" "313" ...
```

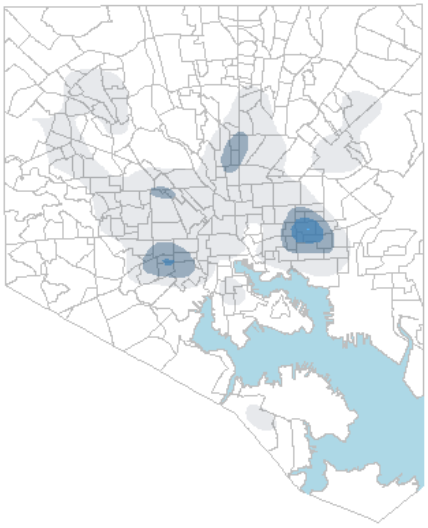
```
# create a plot of 2d kernel density estimates for crime types
# for example : burglary
table(crimeData$description)
```

```
> table(crimeData$description)

        AGG. ASSAULT                 ARSON           AUTO THEFT              BURGLARY        COMMON ASSAULT
HOMICIDE
               25637                  1475                19348                 39795                 47813
1136
             LARCENY     LARCENY FROM AUTO                 RAPE ROBBERY - CARJACKING ROBBERY - COMMERCIAL
ROBBERY - RESIDENCE
               51809                 35373                 1367                   855                  2923
2646
    ROBBERY - STREET              SHOOTING
               13149                  2048
```

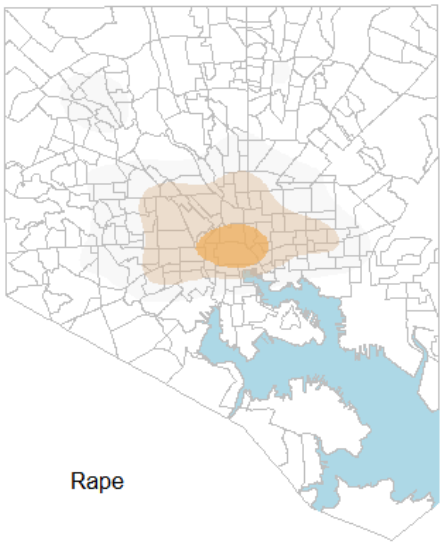
```
p <- neighborhoods  +
      geom_point(data=crimeData[crimeData$description=="BURGLARY",],
                  aes(x=long,y=lat,group=1),shape="x",color="red",alpha=0.8)
```



```
p <- neighborhoods +
     stat_density2d(data=crimeData[crimeData$description=="BURGLARY",],
                    aes(x=long,y=lat,group=1,fill= ..level..,alpha=..level..),
                    size=2,bins=4,geom="polygon")
p
```



```
p <- neighborhoods +
     stat_density2d(data=crimeData[crimeData$description=="RAPE",],
                    aes(x=long,y=lat,group=1,fill= ..level..,alpha=..level..),
                    size=2,bins=4,geom="polygon") +
                    scale_fill_gradient(low="gray",high="orange") +
                    annotate("text",x=1405000,y=565000,label="Rape",size=6)
p
```



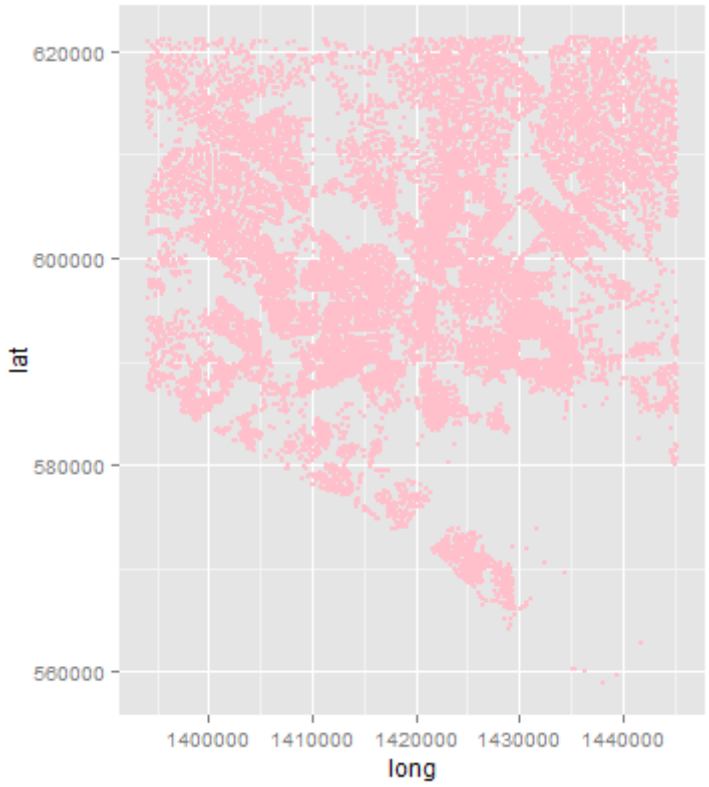
```
p <- neighborhoods +
     stat_density2d(data=crimeData,
                    aes(x=long,y=lat,group=1,fill= ..level..,alpha=..level..),
                    size=2,bins=4,geom="polygon") +
                    scale_fill_gradient(low="lightblue",high="darkred") +
                    facet_wrap(~ description)
p
```

visualizations of 2-dimensional kernel density estimates

# burglay incidents
burg_df <- subset(crimeData,description=="BURGLARY")
str(burg_df)

```
> str(burg_df)
'data.frame':       39795 obs. of  12 variables:
 $ crimeDate   : Factor w/ 1865 levels "01/01/2009","01/01/2010",..: 7 13 13 7 7 31 1 1 1 1
...
 $ crimeTime   : Factor w/ 3785 levels "00:00:00","00:00:11",..: 1081 1719 1898 2200 2233 247
221 337 416 537 ...
 $ crimeCode   : Factor w/ 81 levels "1F","1K","1O",..: 48 45 45 50 48 48 45 49 46 46 ...
 $ location    : Factor w/ 21375 levels "","0 6015 FALLS",..: 9264 18270 3752 15738 7262 2011
12540 20107 21054 5076 ...
 $ description : Factor w/ 14 levels "AGG. ASSAULT",..: 4 4 4 4 4 4 4 4 4 4 ...
 $ weapon      : Factor w/ 5 levels "","FIREARM","HANDS",..: 1 1 1 1 1 1 1 1 1 1 ...
 $ post        : int  223 423 313 534 736 142 224 214 214 321 ...
 $ district    : Factor w/ 10 levels "","CENTRAL","EASTERN",..: 7 4 3 5 10 2 7 7 7 3 ...
 $ neighborhood: Factor w/ 278 levels "","Abell","Allendale",..: 197 142 184 51 162 156 8 84
141 26 ...
 $ Location.1  : Factor w/ 89247 levels "","(37.577260000000003, -81.52919)",..: 27057 85547
44807 75491 52498 39908 25343 15404 19654 48778 ...
 $ lat         : num  592287 618017 597807 611489 600640 ...
 $ long        : num  1432314 1429112 1424617 1408674 1410163 ...
```

ggplot(data=burg_df,aes(x=long,y=lat)) + geom_point(color="pink",size=0.5) + coord_equal()



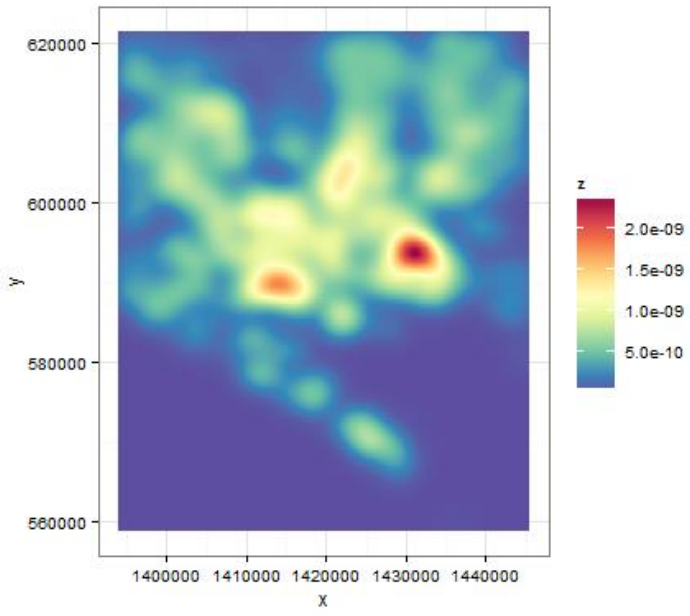
kde2dRange <- c(apply(burg_df[,c("long","lat")], 2,range))
kde2dRange

```
> kde2dRange
[1] 1394047.5 1445374.6  558903.7  621370.4
```

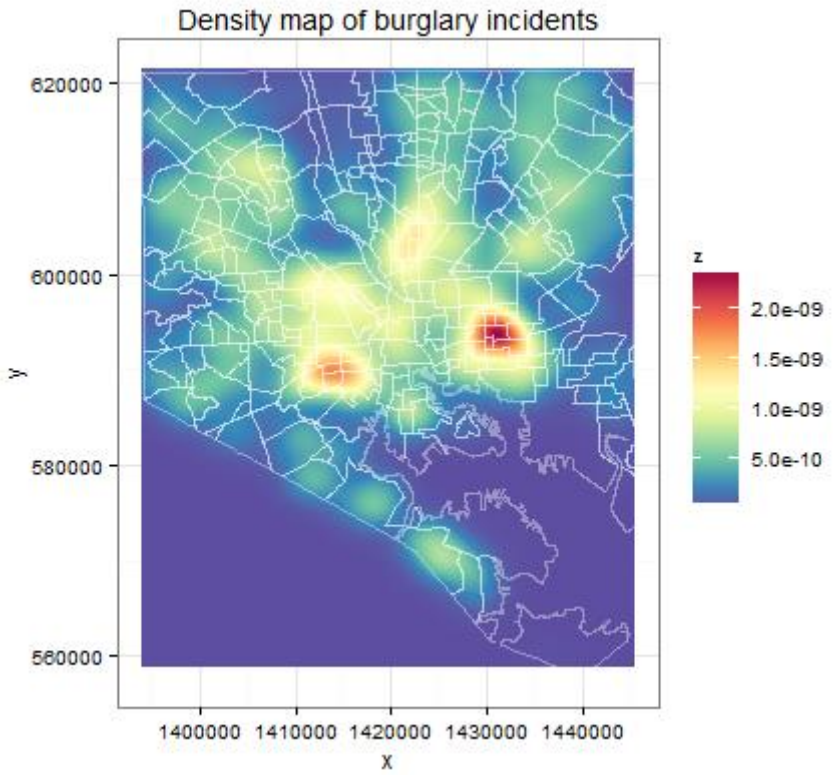
```
library(MASS)

getKde <- function(in_df, N=400, Lims=kde2dRange){
 pts <- as.matrix(in_df[,c('long','lat')])
 dens <- kde2d(pts[,1],pts[,2], n=N, lims=Lims)
 dens_df <- data.frame(expand.grid(dens$x, dens$y), z = c(dens$z))
 colnames(dens_df) <- c('x','y','z')
 return(dens_df)
}

plotKde2d <- function(in_df){
 fillCols <- rev(brewer.pal(11,'Spectral'))
 return(
  ggplot() +
   geom_tile(data = in_df, aes(x=x, y=y, fill=z, group=1)) +
   scale_fill_gradientn(colours=fillCols) +
   theme_bw() +
   coord_equal()
 )
}

# get 2d kernel density estimate
burgDens <- getKde(burg_df)
summary(burgDens)
```

```
> summary(burgDens)
       x                y                z
 Min.   :1394048   Min.   :558904   Min.   :0.000e+00
 1st Qu.:1406879   1st Qu.:574520   1st Qu.:3.581e-12
 Median :1419711   Median :590137   Median :2.150e-10
 Mean   :1419711   Mean   :590137   Mean   :3.043e-10
 3rd Qu.:1432543   3rd Qu.:605754   3rd Qu.:4.822e-10
 Max.   :1445375   Max.   :621370   Max.   :2.346e-09
```

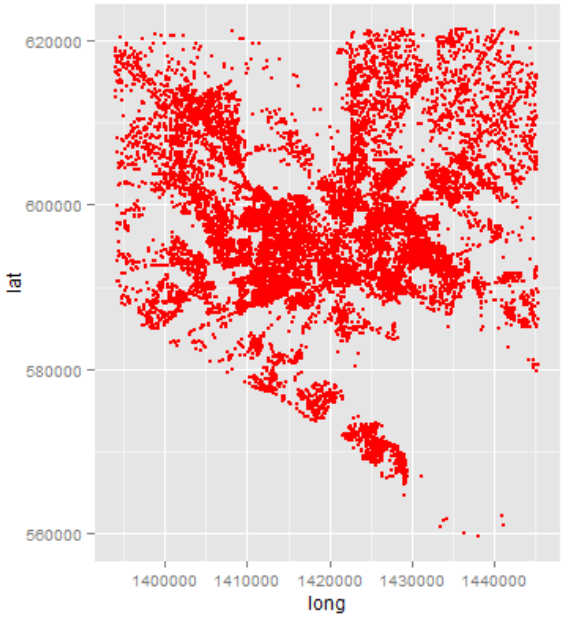
```
# plot 2d kernel density estimate
plotKde2d(burgDens)
```



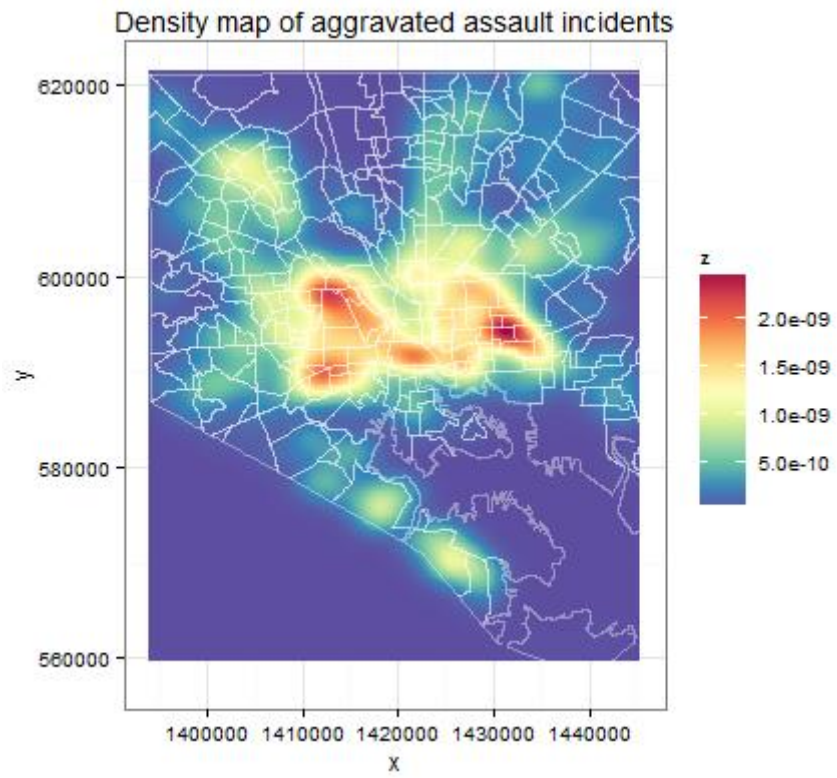
```
plotKde2d(burgDens) +
  geom_path(data=nbhds_pl_df,aes(x=long,y=lat,group=group),color='white',alpha=0.4) +
                ggtitle("Density map of burglary incidents")
```




```
# aggravated assault incidents
aggass_df <- subset(crimeData,description=="AGG. ASSAULT")
str(aggass_df)
ggplot(data=aggass_df,aes(x=long,y=lat)) + geom_point(color="red",size=0.5) + coord_equal()
```



```
kde2dRange <- c(apply(aggass_df[,c("long","lat")], 2,range))
kde2dRange

# get 2d kernel density estimate
aggassDens <- getKde(aggass_df)
summary(aggassDens)

# plot 2d kernel density estimate
library(lattice)
plotKde2d(aggassDens)
plotKde2d(aggassDens) +
  geom_path(data=nbhds_pl_df,aes(x=long,y=lat,group=group),color='white',alpha=0.4) +
  ggtitle("Density map of aggravated assault incidents")
```



```
# Example 18
# point pattern analysis of 311 requests NYC

setwd("c:/R/Rdata/New_York")
data <- read.csv("311_Requests_-_2013.csv",header=T,sep=",")
NYC311 <- subset(data,select=c(Unique.Key,Created.Date,Complaint.Type,Location.Type,Borough,
                    X.Coordinate..State.Plane.,Y.Coordinate..State.Plane.,
                    Latitude,Longitude,Location))

# rename columns
names(NYC311) [names(NYC311)=="Created.Date"] <- c("cdate")
names(NYC311) [names(NYC311)=="X.Coordinate..State.Plane."] <- c("xcoord")
names(NYC311) [names(NYC311)=="Y.Coordinate..State.Plane."] <- c("ycoord")
str(NYC311)
```

```
> str(NYC311)
'data.frame':        1611566 obs. of  10 variables:
 $ Unique.Key     : int  27018310 27023219 27018543 27020971 27020193 27020819 27020680 27018293 27023977
27021537 ...
 $ cdate          : Factor w/ 826316 levels "01/01/2013 01:00:00 PM",..: 826092 826085 826083 826075 826073
826067 826063 826061 826057 826055 ...
 $ Complaint.Type: Factor w/ 192 levels "Adopt-A-Basket",..: 148 148 113 14 151 189 89 175 89 175 ...
 $ Location.Type : Factor w/ 124 levels "","1-2 Family Dwelling",..: 1 1 113 113 82 1 113 1 113 1 ...
 $ Borough        : Factor w/ 6 levels "BRONX","BROOKLYN",..: 4 4 4 4 2 5 2 2 2 2 ...
 $ xcoord         : int  1025967 1026233 1054510 1017826 989760 941450 998045 1001058 982844 NA ...
 $ ycoord         : int  179588 179639 196275 216624 170656 133962 195373 177843 174144 NA ...
 $ Latitude       : num  40.7 40.7 40.7 40.8 40.6 ...
 $ Longitude      : num  -73.8 -73.8 -73.7 -73.9 -74 ...
 $ Location       : Factor w/ 342438 levels "","(40.498737397467444, -74.24051340862874)",..: 99120 99276
175572 257366 72446 2316 171856 94517 86141 1 ...
```

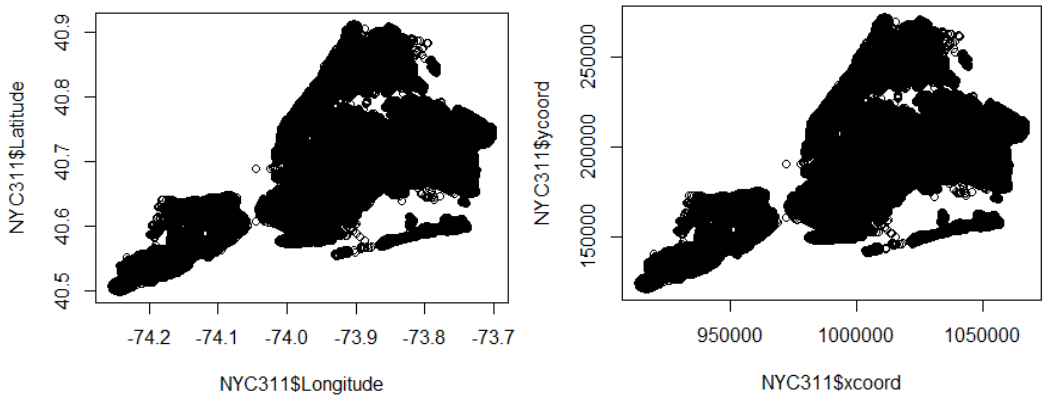
```
# delete records with missing value(s)
NYC311 <- na.omit(NYC311)
dim(NYC311)
```

```
> dim(NYC311)
[1] 1419961      10
```

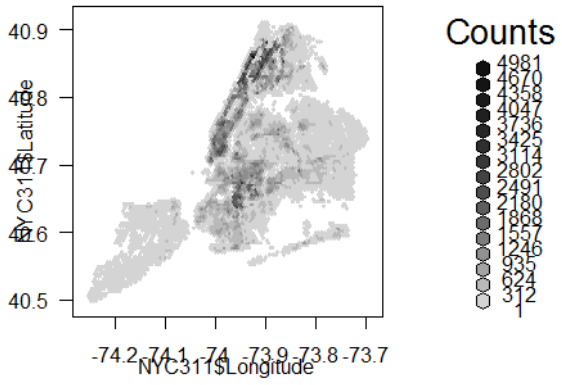
```
# date and time handling
library(lubridate)
library(plyr)
NYC311$cdate1 <- strptime(NYC311$cdate,format="%m/%d/%Y %I:%M:%S %p")
head(NYC311$cdate1)
NYC311$date <- as.Date(NYC311$cdate1,format="%d/%m/%Y")
NYC311$Year <- year(NYC311$date)
NYC311$Month <- month(NYC311$date)
NYC311$Weekday <- wday(NYC311$date)
NYC311$Monthday <- mday(NYC311$date)
NYC311$Monthweek <- ceiling(NYC311$Monthday/7)
NYC311$month <- month(NYC311$date,label=TRUE,abbr=TRUE)
NYC311$weekday <- wday(NYC311$date,label=TRUE,abbr=TRUE)
NYC311$wday <-
factor(NYC311$weekday,order=TRUE,levels=c("Mon","Tues","Wed","Thurs","Fri","Sat","Sun"))
NYC311$wday <-
revalue(NYC311$wday,c("Mon"="Mon","Tues"="Tue","Wed"="Wed","Thurs"="Thu","Fri"="Fri","Sat"
="Sat","Sun"="Sun"))
NYC311$cdate2 <- as.character(NYC311$cdate1)
NYC311$hour <- substr(NYC311$cdate2,12,13)
NYC311$hour <- as.numeric(NYC311$hour)
```

str(NYC311)

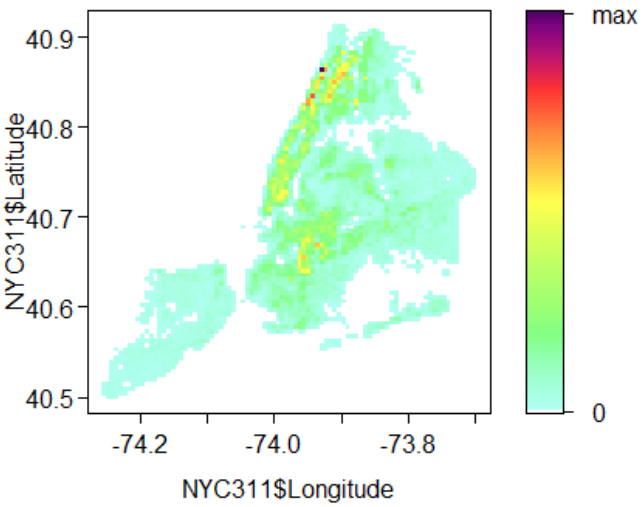
```
> str(NYC311)
'data.frame':         1419961 obs. of  22 variables:
 $ Unique.Key    : int  27018310 27023219 27018543 27020971 27020193 27020819 27020680 27018293 27023977
27022395 ...
 $ cdate         : Factor w/ 826316 levels "01/01/2013 01:00:00 PM",..: 826092 826085 826083 826075 826073
826067 826063 826061 826057 826050 ...
 $ Complaint.Type: Factor w/ 192 levels "Adopt-A-Basket",..: 148 148 113 14 151 189 89 175 89 109 ...
 $ Location.Type : Factor w/ 124 levels "","1-2 Family Dwelling",..: 1 1 113 113 82 1 113 1 113 28 ...
 $ Borough       : Factor w/ 6 levels "BRONX","BROOKLYN",..: 4 4 4 4 2 5 2 2 2 3 ...
 $ xcoord        : int  1025967 1026233 1054510 1017826 989760 941450 998045 1001058 982844 994613 ...
 $ ycoord        : int  179588 179639 196275 216624 170656 133962 195373 177843 174144 215497 ...
 $ Latitude      : num  40.7 40.7 40.7 40.8 40.6 ...
 $ Longitude     : num  -73.8 -73.8 -73.7 -73.9 -74 ...
 $ Location      : Factor w/ 342438 levels "","(40.498737397467444, -74.24051340862874)",..: 99120 99276
175572 257366 72446 2316 171856 94517 86141 252562 ...
 $ cdate1        : POSIXlt, format: "2013-12-31 23:59:00" "2013-12-31 23:57:00" "2013-12-31 23:56:54"
"2013-12-31 23:54:26" ...
 $ date          : Date, format: "2013-12-31" "2013-12-31" "2013-12-31" "2013-12-31" ...
 $ Year          : num  2013 2013 2013 2013 2013 ...
 $ Month         : num  12 12 12 12 12 12 12 12 12 12 ...
 $ Weekday       : num  3 3 3 3 3 3 3 3 3 3 ...
 $ Monthday      : int  31 31 31 31 31 31 31 31 31 31 ...
 $ Monthweek     : num  5 5 5 5 5 5 5 5 5 5 ...
 $ month         : Ord.factor w/ 12 levels "Jan"<"Feb"<"Mar"<..: 12 12 12 12 12 12 12 12 12 12 ...
 $ weekday       : Ord.factor w/ 7 levels "Sun"<"Mon"<"Tues"<..: 3 3 3 3 3 3 3 3 3 3 ...
 $ wday          : Ord.factor w/ 7 levels "Mon"<"Tue"<"Wed"<..: 2 2 2 2 2 2 2 2 2 2 ...
 $ cdate2        : chr  "2013-12-31 23:59:00" "2013-12-31 23:57:00" "2013-12-31 23:56:54" "2013-12-31
23:54:26" ...
 $ hour          : num  23 23 23 23 23 23 23 23 23 23 ...
 - attr(*, "na.action")=Class 'omit'  Named int [1:191605] 10 24 31 34 69 83 92 93 94 95 ...
  .. ..- attr(*, "names")= chr [1:191605] "10" "24" "31" "34" ...
```



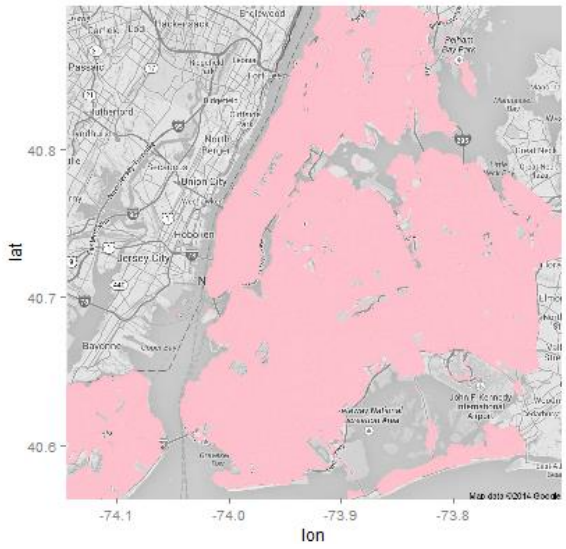
library(hexbin)
bin <- hexbin(NYC311$Longitude,NYC311$Latitude,xbin=100)
plot(bin)



```
library(IDPmisc)
iplot(NYC311$Longitude,NYC311$Latitude)
```



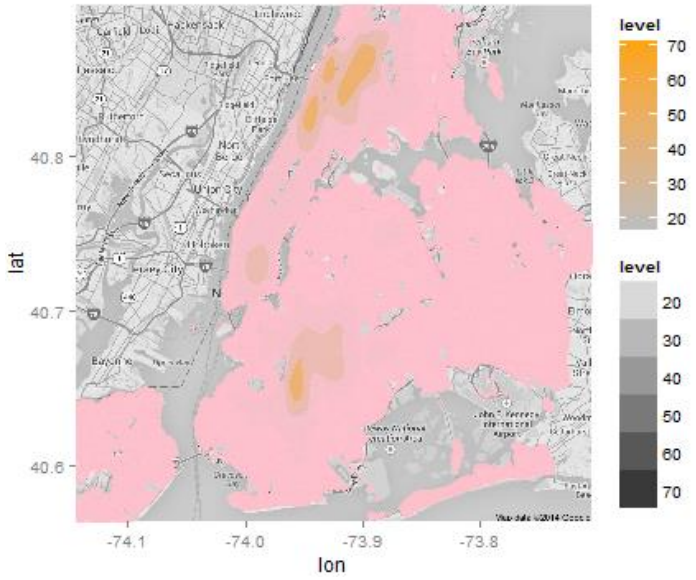

```
mean(NYC311$Longitude)
mean(NYC311$Latitude)
library(ggmap)
NYC <- c(lon=-73.92507,lat=40.73083)
map <- get_map(NYC,zoom=11,color="bw")
map <- ggmap(map,extent="panel")
map

library(ggplot2)
map <- map + geom_point(data=NYC311,aes(x=Longitude,y=Latitude),alpha=0.2,color="pink")
map
```



```
map <- map +
    stat_density2d(data=NYC311,aes(x=Longitude,y=Latitude,group=1,fill=..level..,alpha=..level..),
                size=2,bins=4,geom="polygon") +
                scale_fill_gradient(low="gray",high="orange")
map
```

Error : cannot allocate vector of size 1.0 Gb

```
nyc311_ <- subset(NYC311,month=="Jan",select=c(Longitude,Latitude))
str(nyc311_)

map <- map +
 stat_density2d(data=nyc311_,aes(x=Longitude,y=Latitude,group=1,fill=..level..,alpha=..level..),
            size=2,bins=4,geom="polygon") +
            scale_fill_gradient(low="gray",high="orange")
map
```




```
library(rgdal)
NYC <- readOGR(".","nymcwi")
plot(NYC)
proj4string(NYC)
```

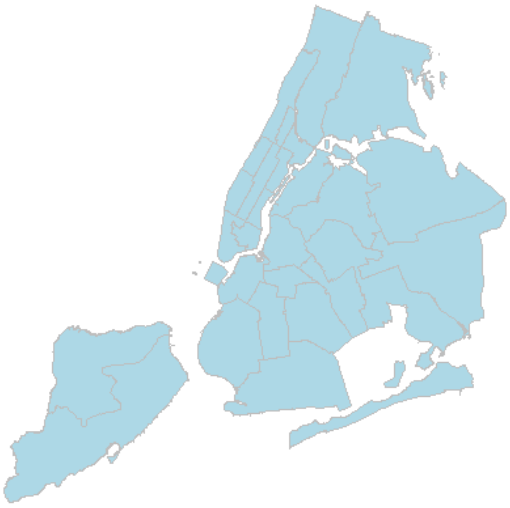
```
> proj4string(NYC)
[1] "+proj=lcc +lat_1=40.66666666666666 +lat_2=41.03333333333333 +lat_0=40.16666666666666 +lon_0=-74
+x_0=300000 +y_0=0 +datum=NAD83 +units=us-ft +no_defs +ellps=GRS80 +towgs84=0,0,0"
```

```
origProj <- NYC@proj4string
```

```
# to work with ggplot we fortify the shapefile
NYC_df <- fortify(NYC)
str(NYC_df)
```

```
> str(NYC_df)
'data.frame':         30910 obs. of  7 variables:
 $ long : num  1025415 1025139 1025063 1024869 1024752 ...
 $ lat  : num  270986 270558 270436 270134 269950 ...
 $ order: int  1 2 3 4 5 6 7 8 9 10 ...
 $ hole : logi  FALSE FALSE FALSE FALSE FALSE FALSE ...
 $ piece: Factor w/ 12 levels "1","2","3","4",..: 1 1 1 1 1 1 1 1 1 1 ...
 $ group: Factor w/ 48 levels "0.1","0.2","0.3",..: 1 1 1 1 1 1 1 1 1 1 ...
 $ id   : chr  "0" "0" "0" "0" ...
```

```
baseplot <- ggplot(data=NYC_df,aes(x=long,y=lat,group=group)) +
                    geom_polygon(color="gray",fill="lightblue") +
                    coord_equal() + theme_nothing()
baseplot
```



```
# convert the lat/long coordinates of 311 datafile to the original projection
str(nyc311_)

nyc311_spdf <- SpatialPoints(nyc311_,proj4string=CRS("+proj=longlat +datum=WGS84"))
class(nyc311_spdf)
nyc311_spdf <- spTransform(nyc311_spdf,origProj)
proj4string(nyc311_spdf)
```

```
> proj4string(nyc311_spdf)
[1] "+proj=lcc +lat_1=40.66666666666666 +lat_2=41.03333333333333 +lat_0=40.16666666666666 +lon_0=-74
+x_0=300000 +y_0=0 +datum=NAD83 +units=us-ft +no_defs +ellps=GRS80 +towgs84=0,0,0"
```

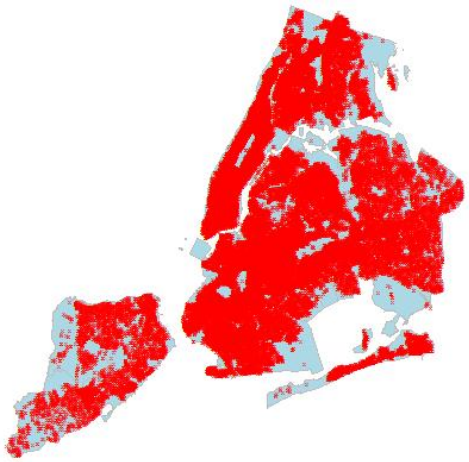
```
nyc311_spdf_coords <- coordinates(nyc311_spdf)
str(nyc311_spdf_coords)
```

```
> str(nyc311_spdf_coords)
 num [1:143564, 1:2] 984336 984535 989102 1038981 1038981 ...
 - attr(*, "dimnames")=List of 2
  ..$ : NULL
  ..$ : chr [1:2] "Longitude" "Latitude"
```

```
nyc311_$long <- nyc311_spdf_coords[,1]
nyc311_$lat <- nyc311_spdf_coords[,2]
str(nyc311_)
```

```
> str(nyc311_)
'data.frame':         143564 obs. of  4 variables:
 $ Longitude: num  -74 -74 -74 -73.8 -73.8 ...
 $ Latitude : num  40.7 40.7 40.8 40.7 40.7 ...
 $ long     : num  984336 984535 989102 1038981 1038981 ...
 $ lat      : num  201715 210565 224912 185066 185066 ...
```

```
p <- baseplot +
geom_point(data=nyc311_,aes(x=long,y=lat,group=1),shape="x",color="red",alpha=0.8)
p
```

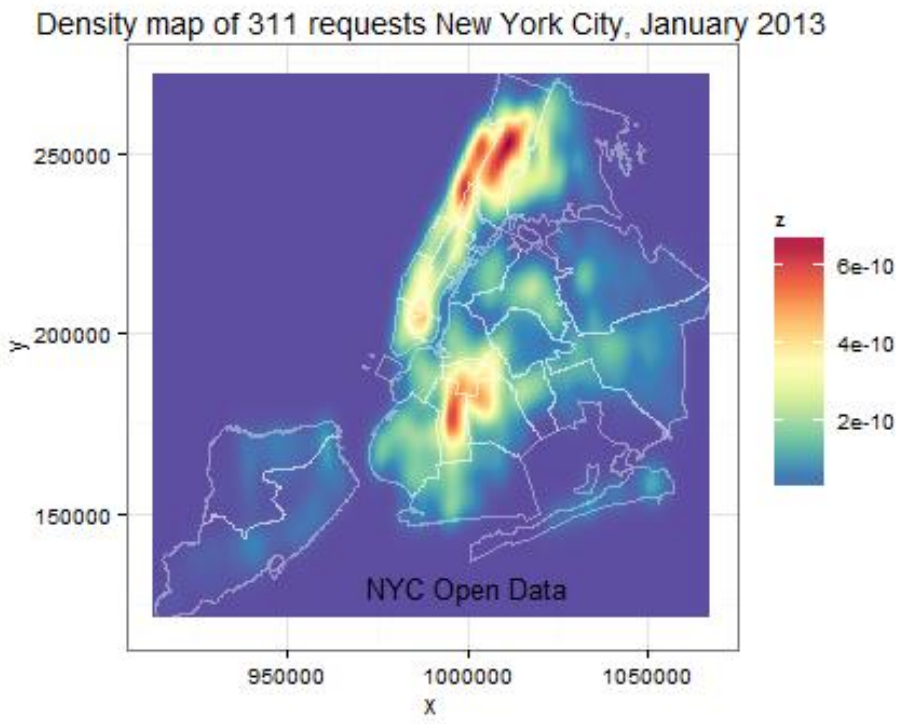


```
# visualization of 2-dimensional kernel density estimates

kde2dRange <- c(apply(nyc311_[,c("long","lat")],2,range))
kde2dRange
library(MASS)

getKde <- function(in_df, N=400, Lims=kde2dRange){
  pts <- as.matrix(in_df[,c('long','lat')])
  dens <- kde2d(pts[,1],pts[,2], n=N, lims=Lims)
  dens_df <- data.frame(expand.grid(dens$x, dens$y), z = c(dens$z))
  colnames(dens_df) <- c('x','y','z')
  return(dens_df)
}

plotKde2d <- function(in_df){
  fillCols <- rev(brewer.pal(11,'Spectral'))
  return(
    ggplot() +
      geom_tile(data = in_df, aes(x=x, y=y, fill=z, group=1)) +
      scale_fill_gradientn(colours=fillCols) +
      theme_bw() +
      coord_equal()
  )
}
```

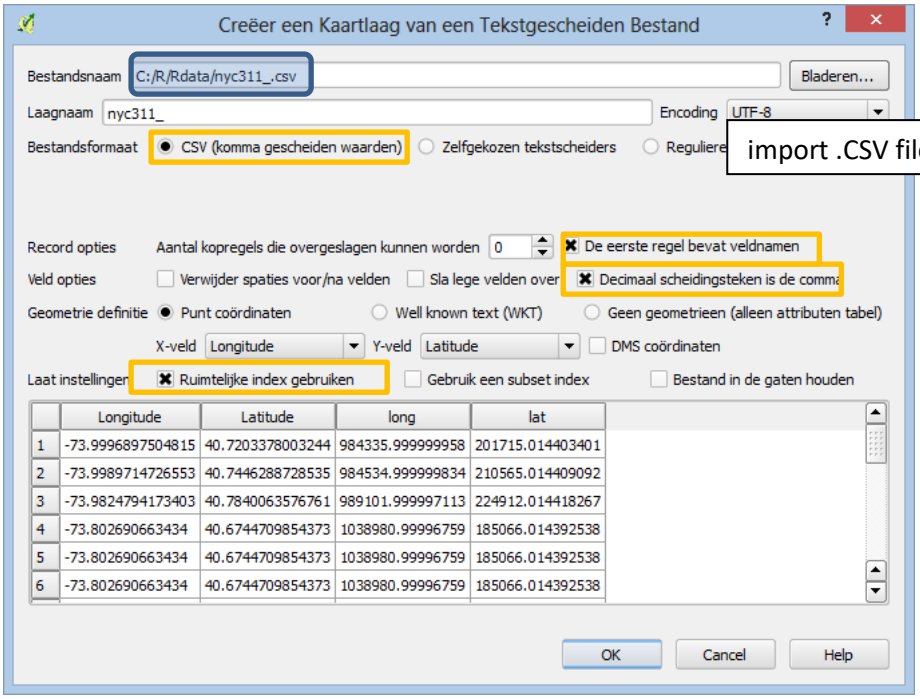
```
# get 2d kernel density estimate
nyDens <- getKde(nyc311_)
summary(nyDens)
```

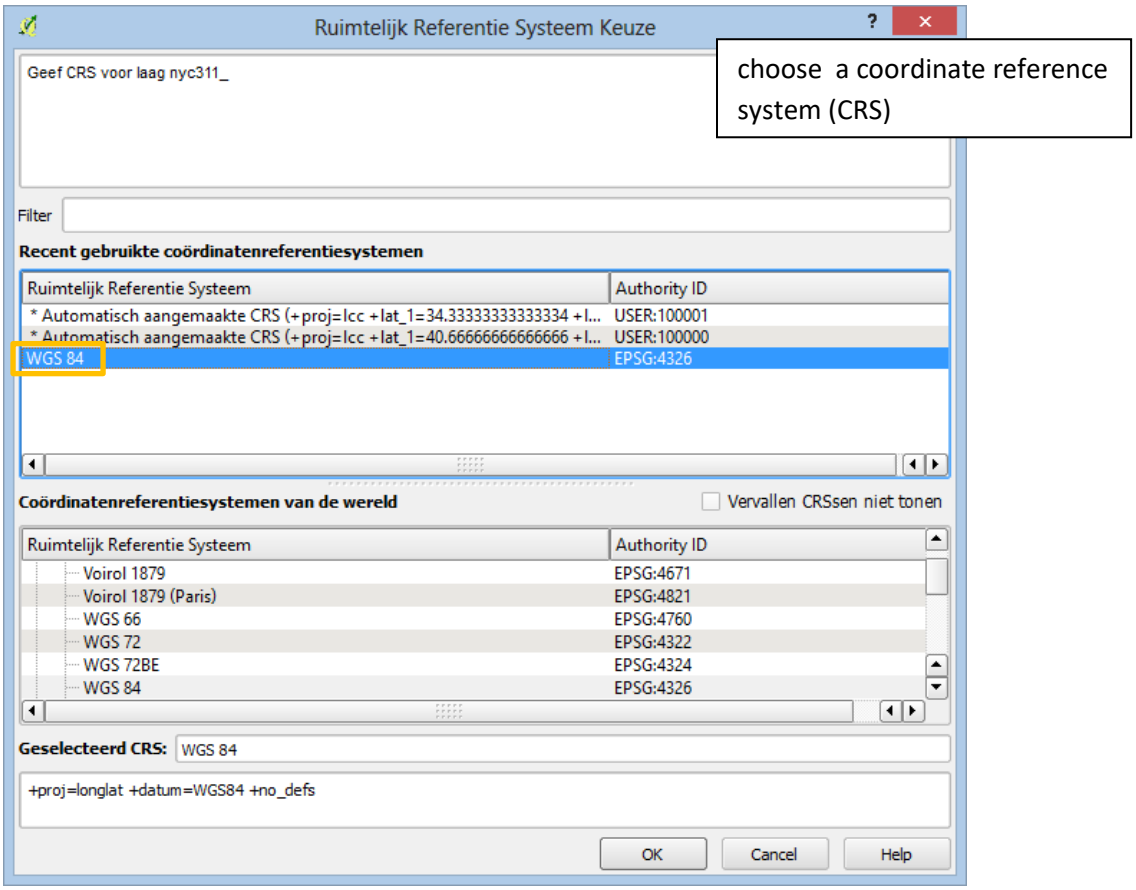
```
> summary(nyDens)
       x                y                z
 Min.   : 913371   Min.   :121179   Min.   :0.000e+00
 1st Qu.: 951833   1st Qu.:158850   1st Qu.:0.000e+00
 Median : 990296   Median :196520   Median :5.566e-13
 Mean   : 990296   Mean   :196520   Mean   :4.288e-11
 3rd Qu.:1028758   3rd Qu.:234191   3rd Qu.:4.242e-11
 Max.   :1067220   Max.   :271861   Max.   :6.861e-10
```

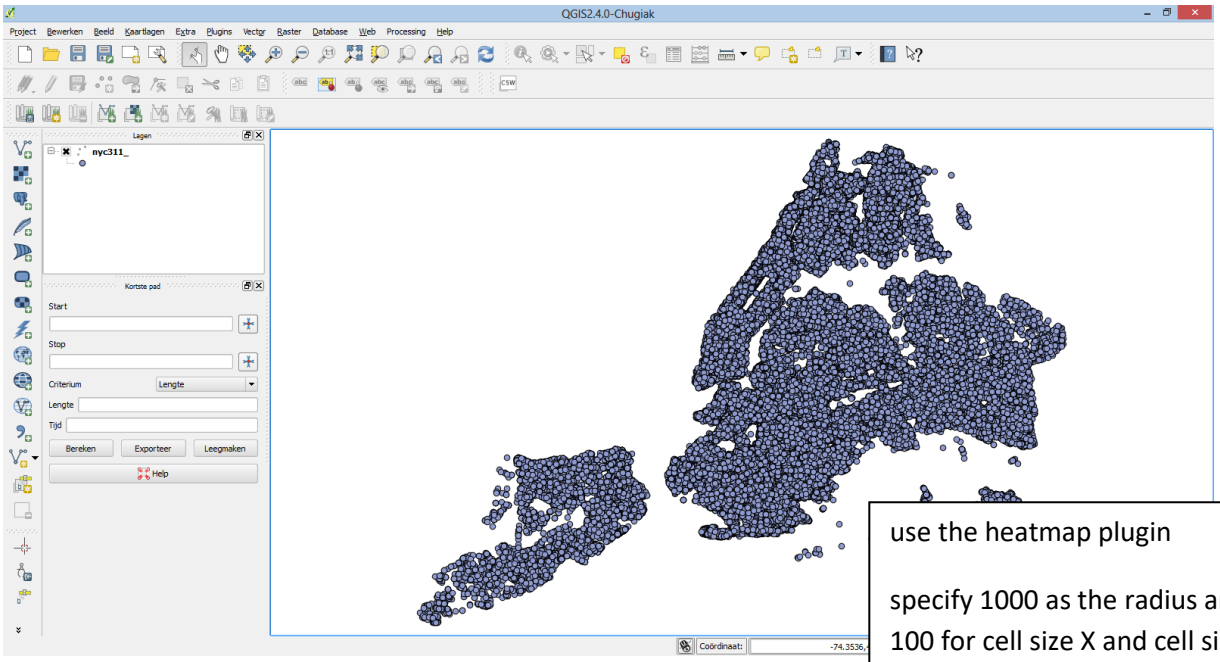
```
library(RColorBrewer)
# plot 2d kernel density estimate
plotKde2d(nyDens)
plotKde2d(nyDens) +
 geom_path(data=NYC_df,aes(x=long,y=lat,group=group),color='white',alpha=0.4) +
 ggtitle("Density map of 311 requests New York City, January 2013") +
 annotate("text",x=1000000,y=130000,label="NYC Open Data",size=4.5)
```



heatmap in Quantum Gis (2.4) with nyc311_ data



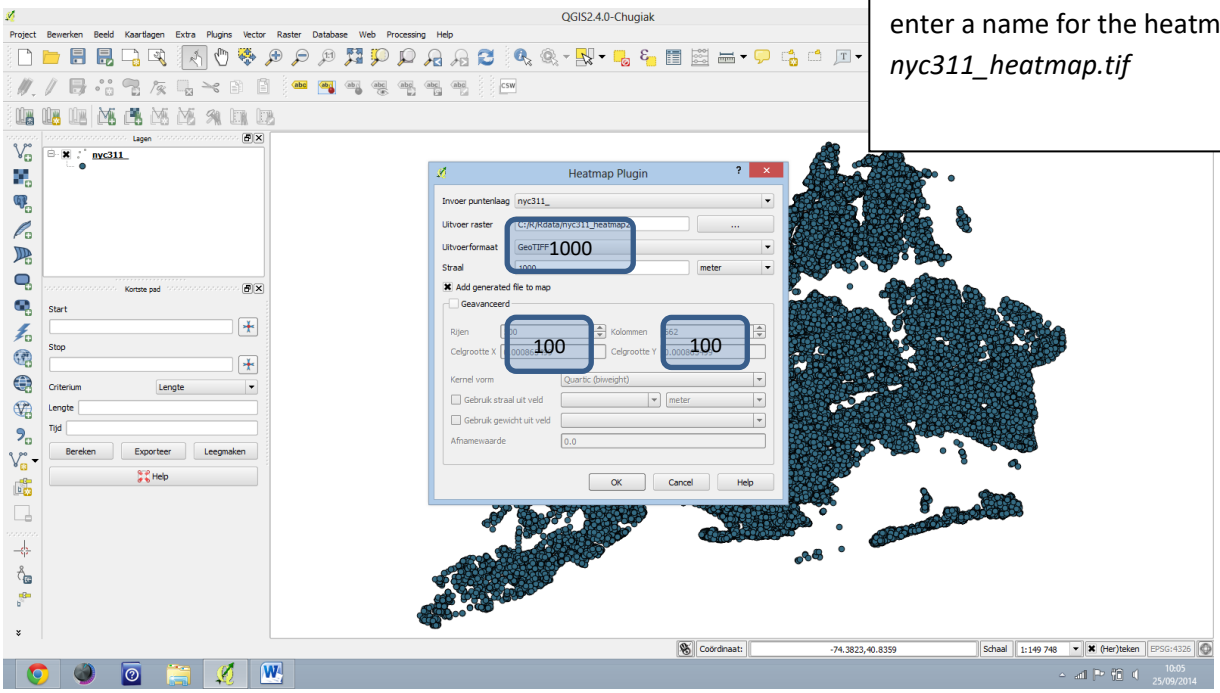


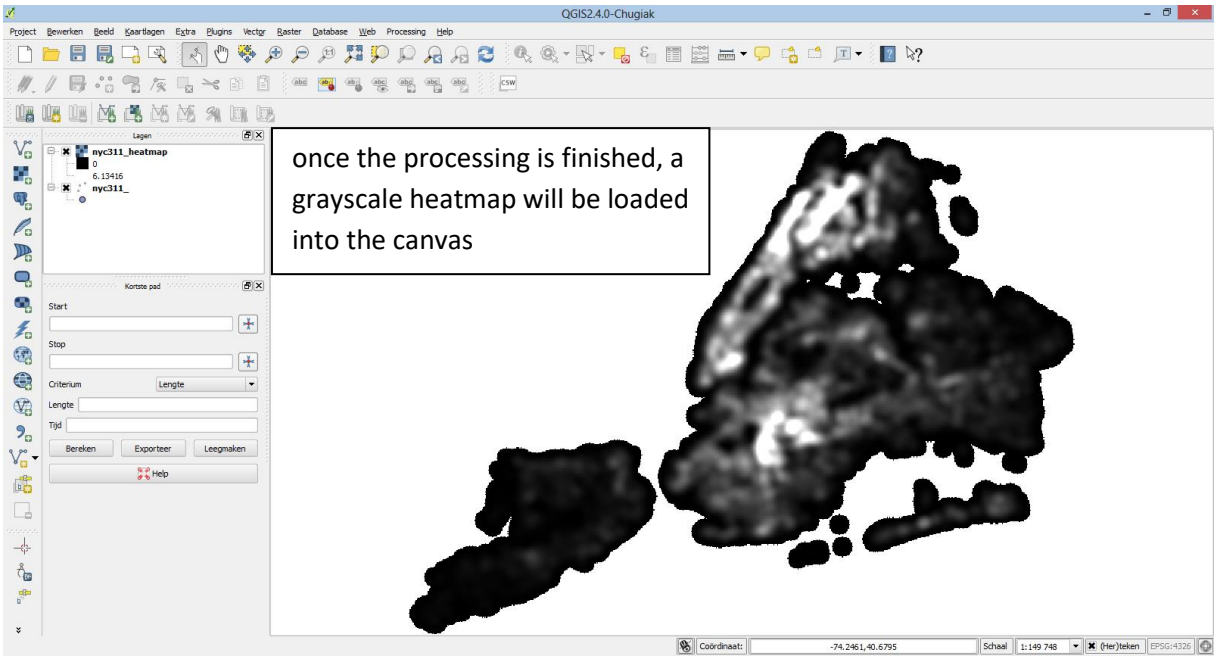


use the heatmap plugin

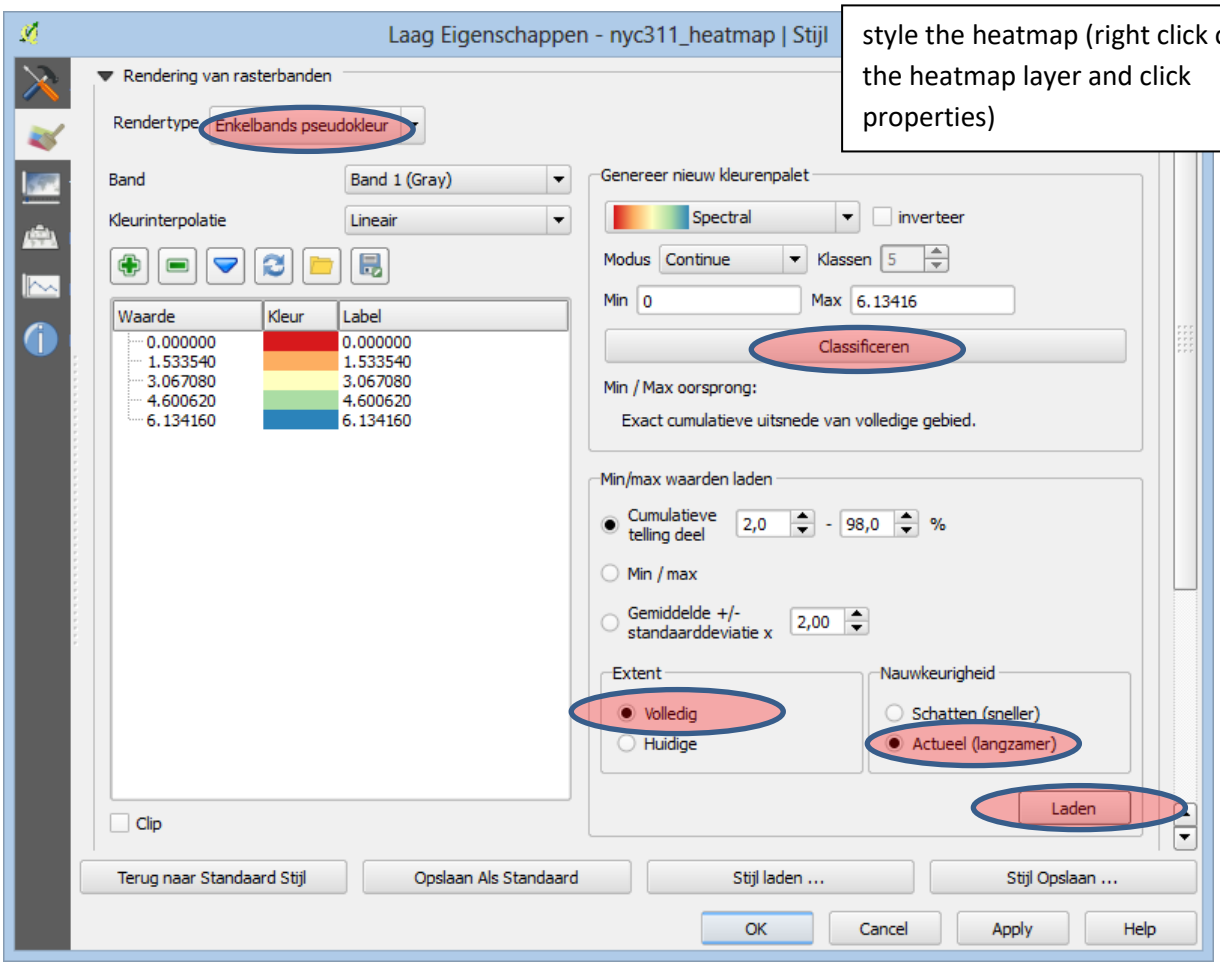
specify 1000 as the radius and enter 100 for cell size X and cell size Y

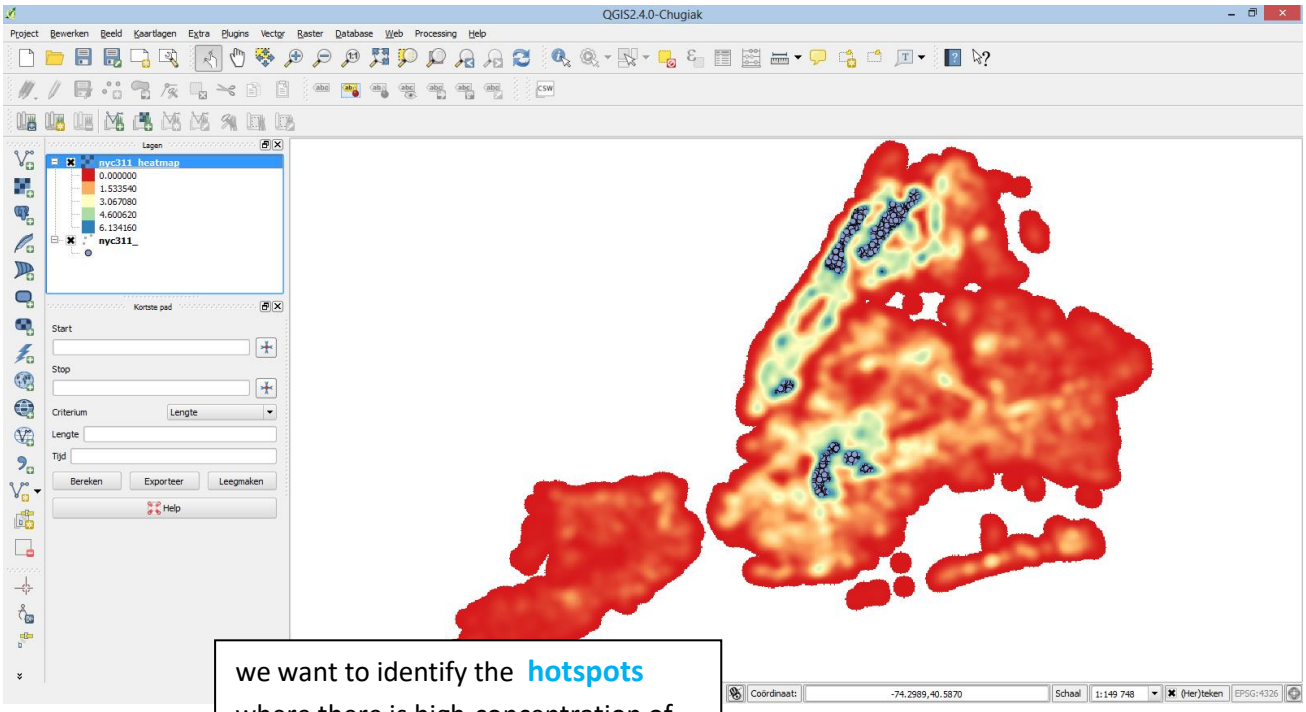
enter a name for the heatmap : *nyc311_heatmap.tif*



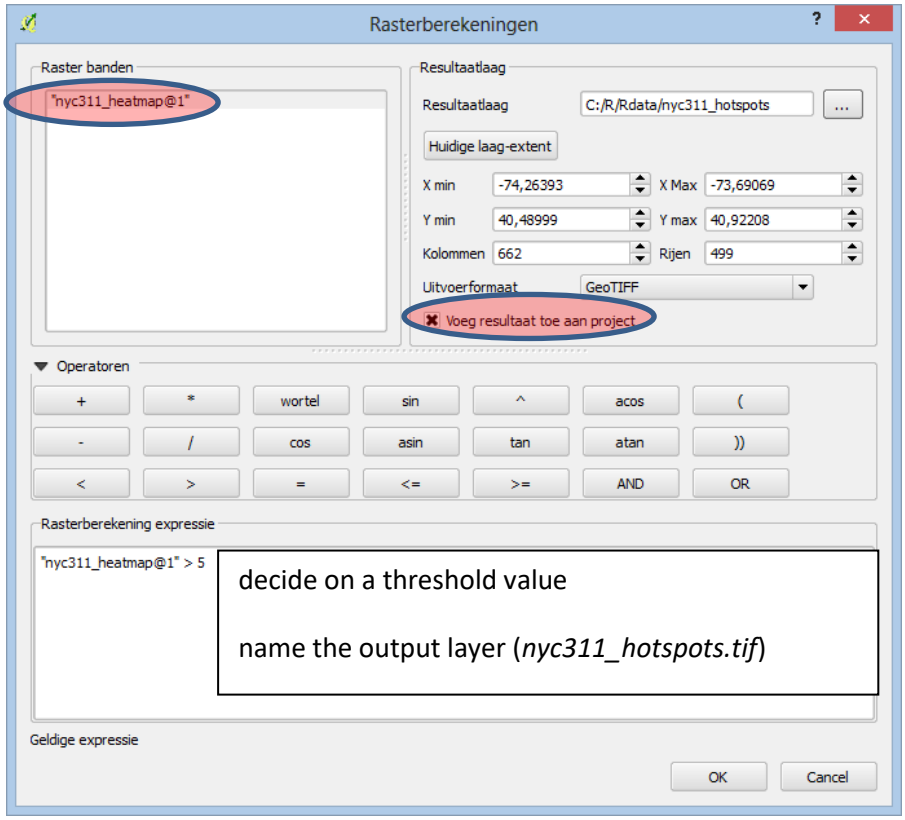


style the heatmap (right click on the heatmap layer and click properties)



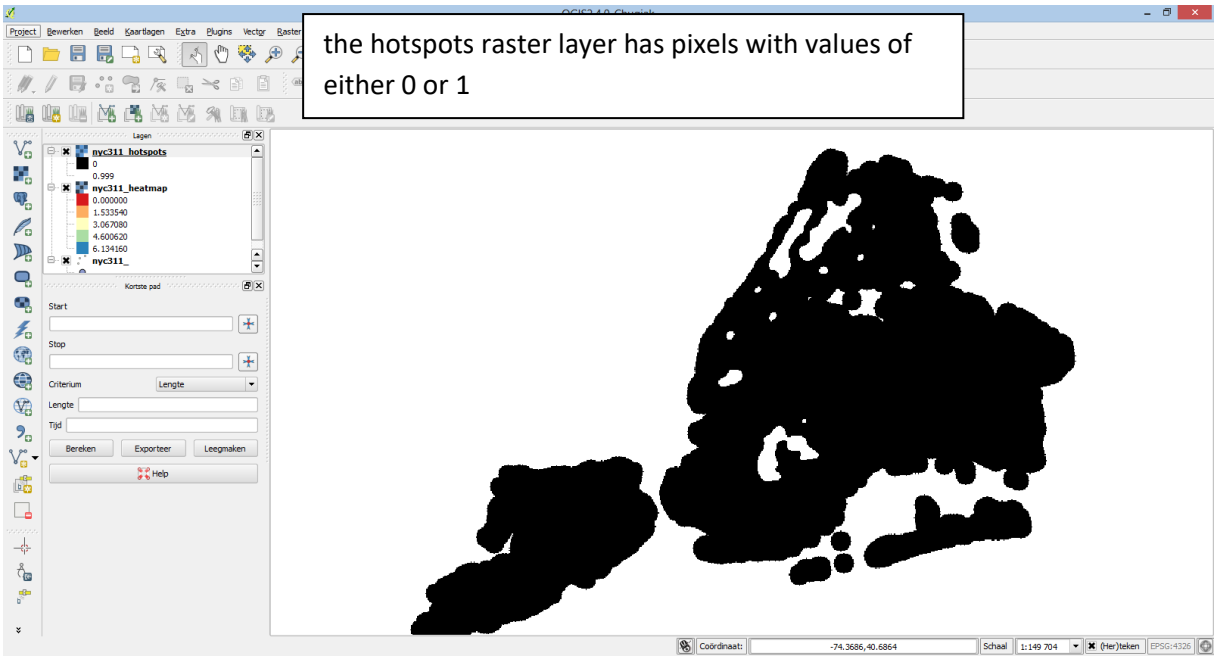


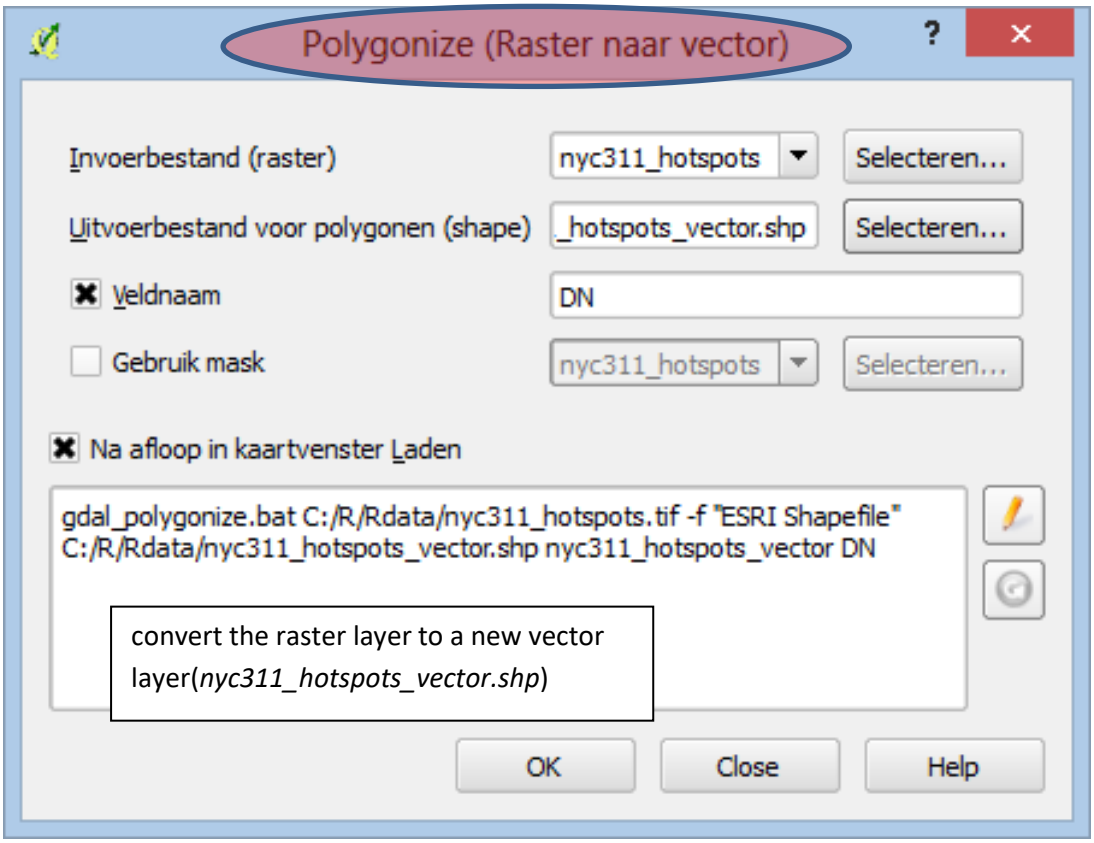
we want to identify the **hotspots** where there is high-concentration of points (go to raster > raster calculator)

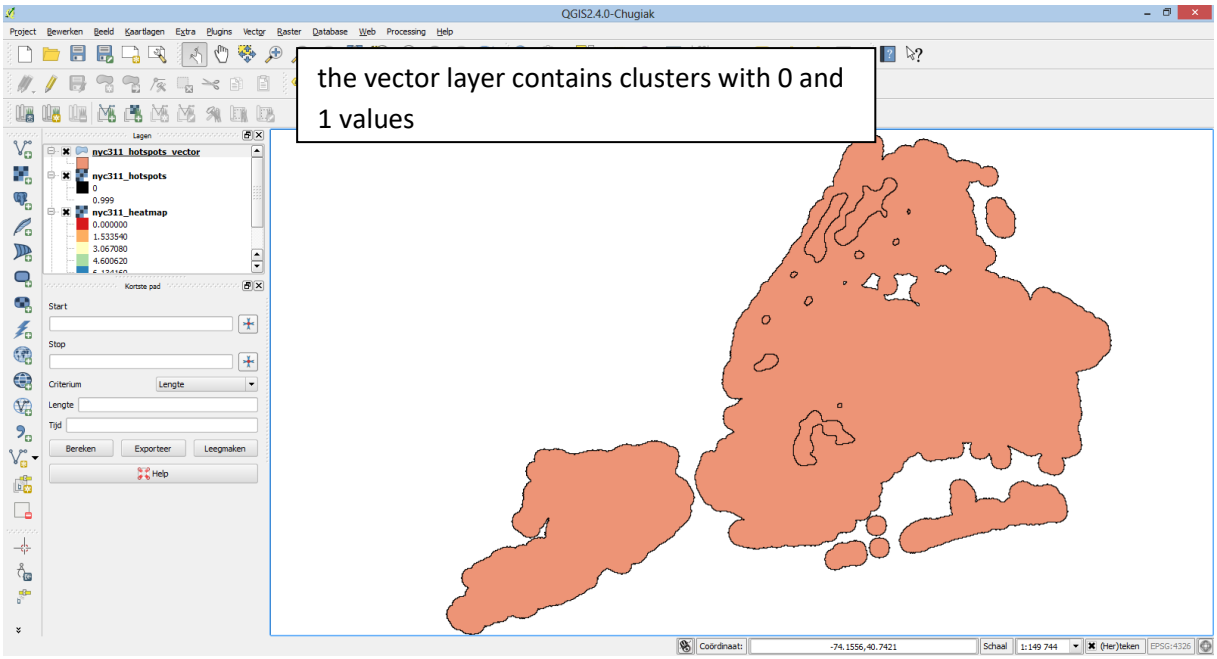


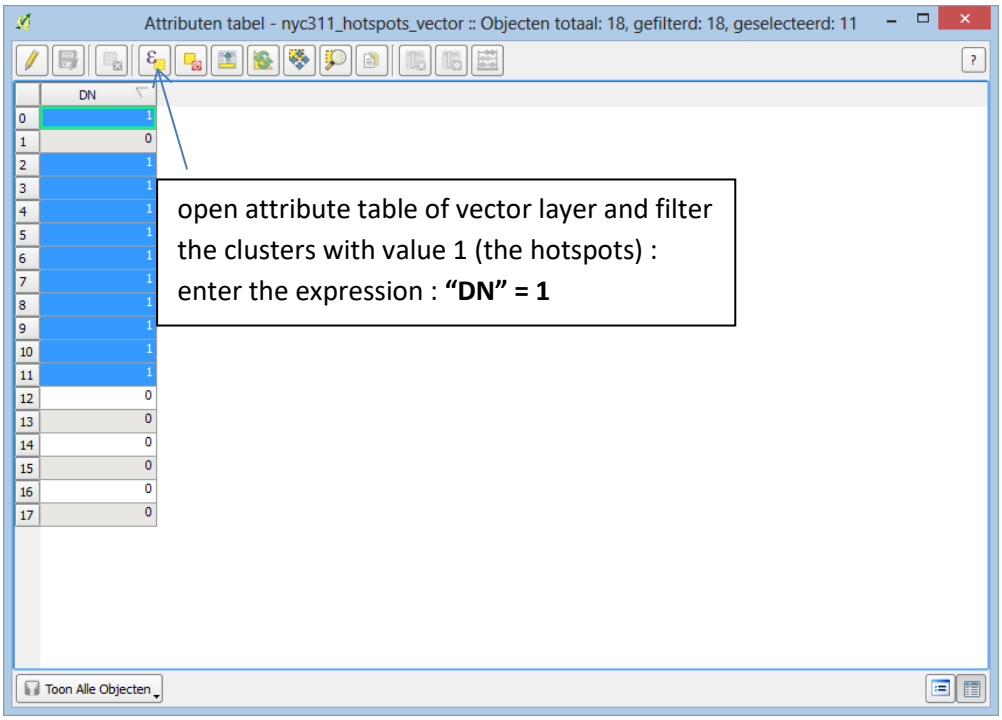
decide on a threshold value

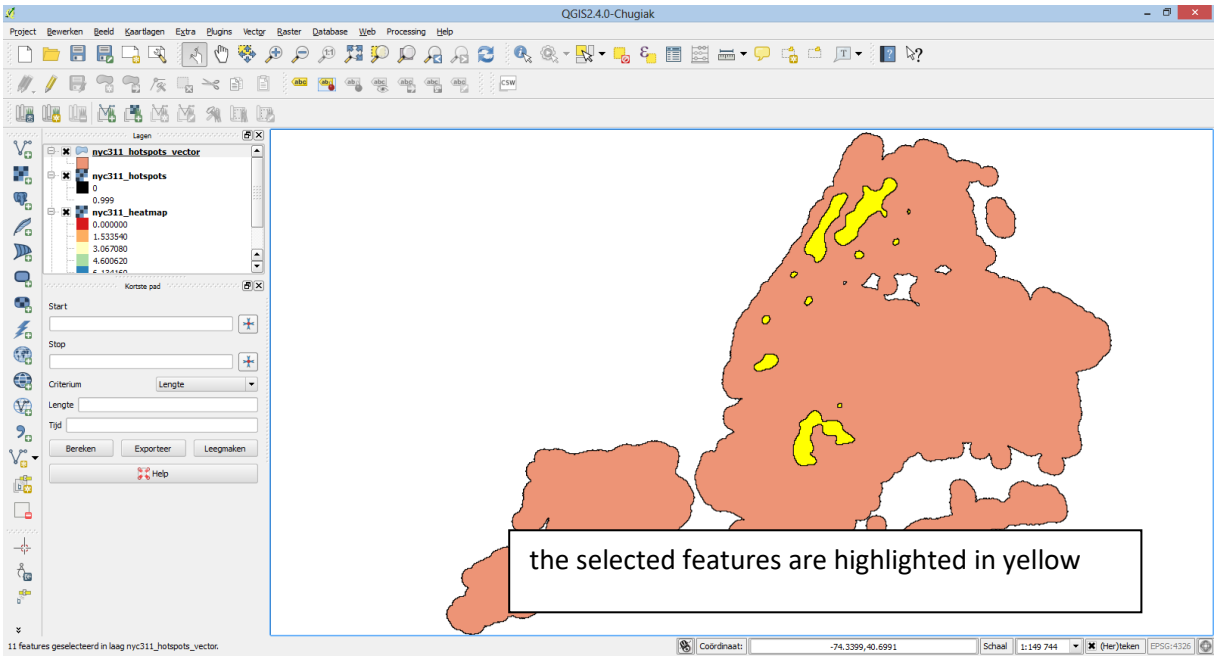
name the output layer (*nyc311_hotspots.tif*)

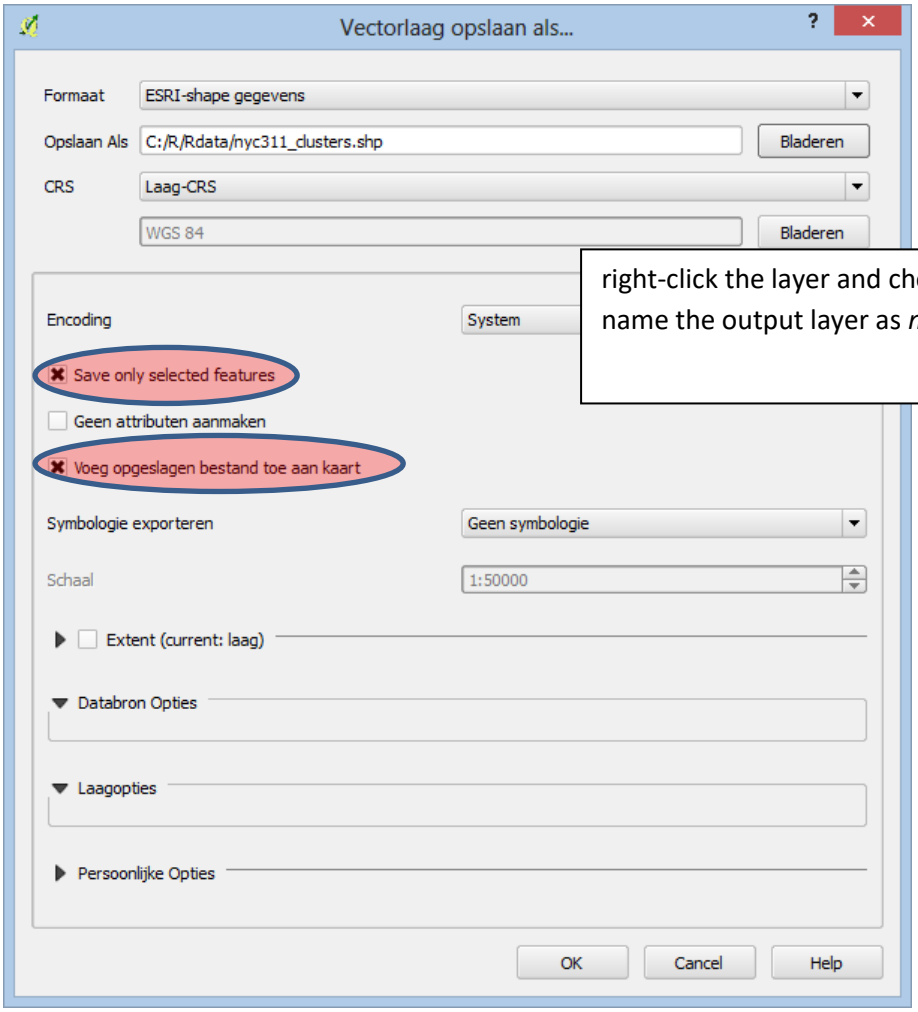

the hotspots raster layer has pixels with values of either 0 or 1
nyc311_hotspots
nyc311_heatmap
Start
Stop
Criterium
Lengte
Tijd
Bereken
Exporteer
Leegmaken
Help


Polygonize (Raster naar vector)
Invoerbestand (raster)
nyc311_hotspots
Selecteren...
Uitvoerbestand voor polygonen (shape)
_hotspots_vector.shp
Selecteren...
Veldnaam
DN
Gebruik mask
nyc311_hotspots
Selecteren...
Na afloop in kaartvenster Laden
gdal_polygonize.bat C:/R/Rdata/nyc311_hotspots.tif -f "ESRI Shapefile" C:/R/Rdata/nyc311_hotspots_vector.shp nyc311_hotspots_vector DN
convert the raster layer to a new vector layer(nyc311_hotspots_vector.shp)
OK
Close
Help

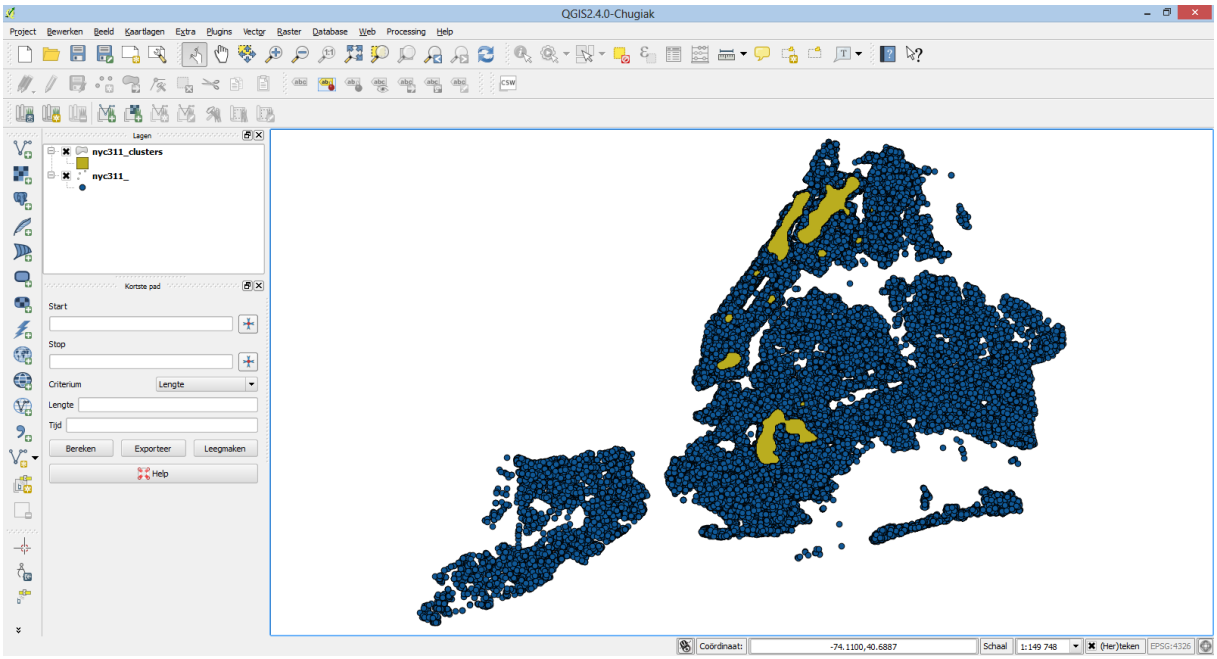

QGIS2.4.0-Chugiak
the vector layer contains clusters with 0 and 1 values
nyc311_hotspots_vector
nyc311_hotspots
nyc311_heatmap

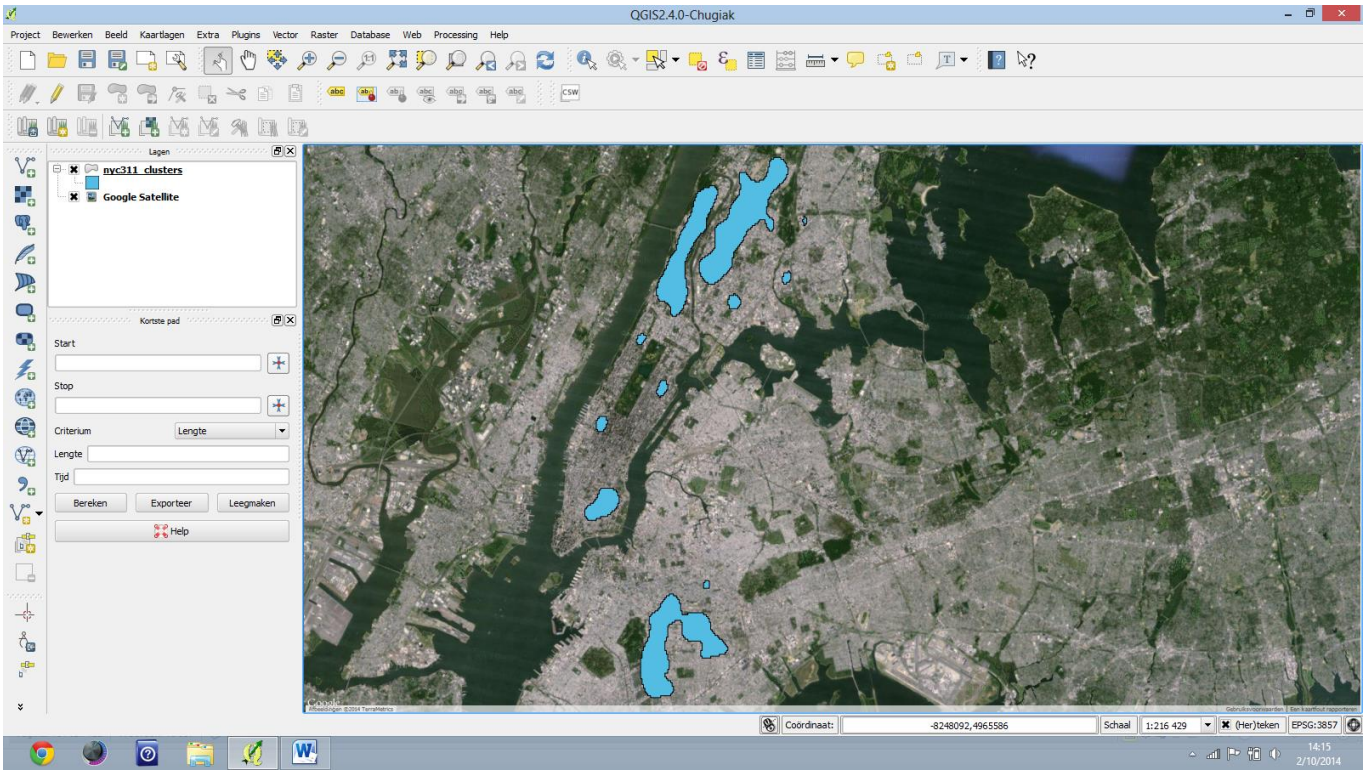

Attributen tabel - nyc311_hotspots_vector :: Objecten totaal: 18, gefilterd: 18, geselecteerd: 11
DN
open attribute table of vector layer and filter the clusters with value 1 (the hotspots) : enter the expression : **"DN" = 1**
Toon Alle Objecten

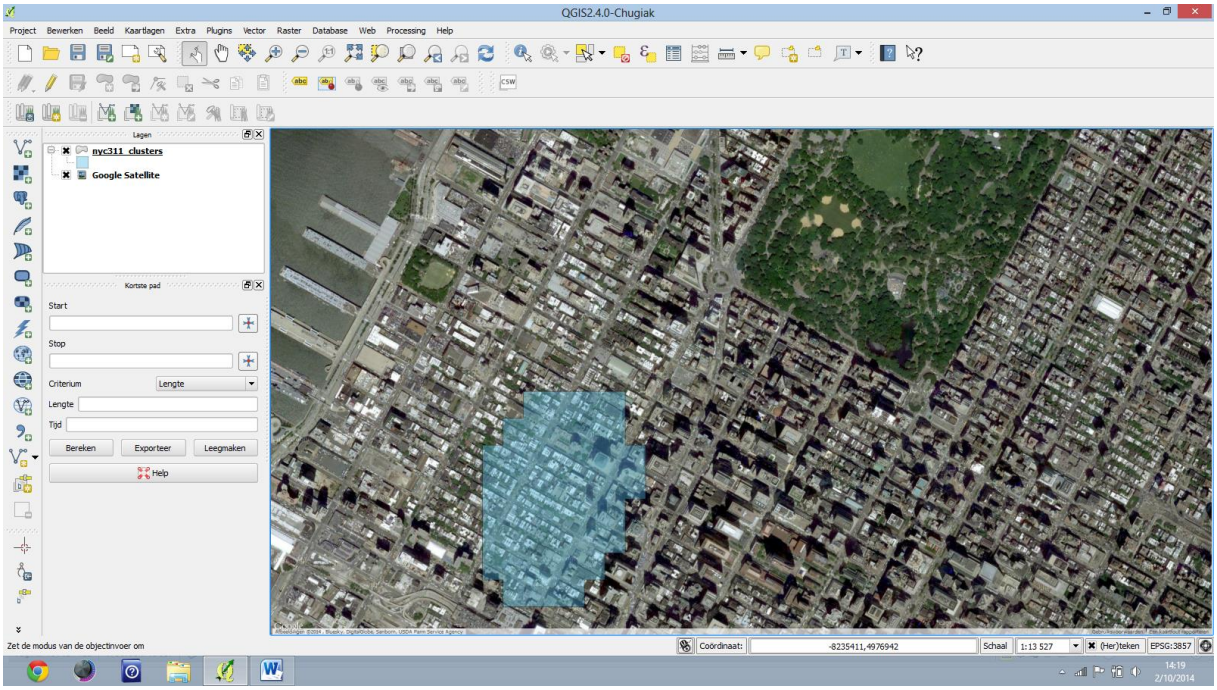




right-click the layer and choose “save Selection As” : name the output layer as *nyc311_clusters.shp*


QGIS2.4.0-Chugiak
Project Bewerken Beeld Kaartlagen Extra Plugins Vector Raster Database Web Processing Help
Lagen
nyc311_clusters
nyc311_
Kortste pad
Start
Stop
Criterium
Lengte
Lengte
Tijd
Bereken
Exporteer
Leegmaken
Help
Coördinaat:
-74.1100,40.6887
Schaal
1:149 748
(Her)teken
EPSG:4326

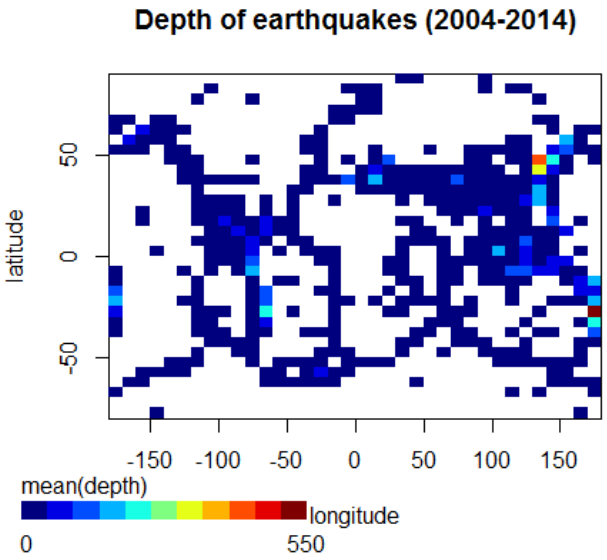

QGIS2.4.0-Chugiak
Project Bewerken Beeld Kaartlagen Extra Plugins Vector Raster Database Web Processing Help
Lagen
nyc311_clusters
Google Satellite
Kortste pad
Start
Stop
Criterium
Lengte
Lengte
Tijd
Bereken
Exporteer
Leegmaken
Help
Coördinaat:
-8248092,4965586
Schaal
1:216 429
(Her)teken
EPSG:3857


QGIS2.4.0-Chugiak
Project Bewerken Beeld Kaartlagen Extra Plugins Vector Raster Database Web Processing Help
Legen
nyc311_clusters
Google Satellite
Kortste pad
Start
Stop
Criterium
Lengte
Lengte
Tijd
Bereken
Exporteer
Leegmaken
Help
Zet de modus van de objectinvoer om
Coördinaat:
-8235411, 4976942
Schaal
1:13 527
(Her)teken
EPSG:3857
14:19
2/10/2014

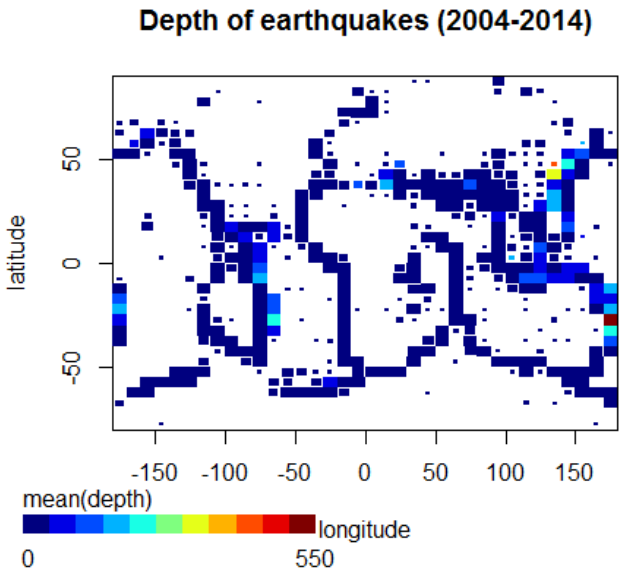
```
# Example 19
# point patterns can also be visualized with package "squash"
# this package provides functions for color-based visualization of multivariate data
# base question : given a large number of 3-dimensional points (x,y,z),
# how does z vary as a function of x and y ?

setwd("c:/R/Rdata")
catalog <- read.csv("earthquake-catalog.csv",header=T,sep=",",stringsAsFactors=FALSE)

# date and time handling
library(lubridate)
library(plyr)
catalog$time <- sub("T"," ",catalog$time)
catalog$time <- sub("Z","",catalog$time)
catalog$time <- strptime(catalog$time, format="%Y-%m-%d %H:%M:%S")
catalog$date <- as.Date(catalog$time)
catalog$year <- year(catalog$time)
str(catalog)
```

```
> str(catalog)
'data.frame':         20000 obs. of  17 variables:
 $ time     : POSIXlt, format: "2014-04-24 03:20:14" "2014-04-24 03:10:12" "2014-04-24 02:17:30" "2014-04-
23 22:25:07" ...
 $ latitude : num  49.9 49.8 -10.8 27.5 -23.8 ...
 $ longitude: num  -127 -127 166 129 -180 ...
 $ depth    : num  10 11.4 40.6 37.3 533.4 ...
 $ mag      : num  5 6.6 5.1 5 5 5.1 5 5.4 5.4 5.3 ...
 $ magType  : chr  "mb" "mww" "mb" "mb" ...
 $ nst      : int  NA NA NA NA NA NA NA NA NA NA ...
 $ gap      : num  182 41 40 112 45 54 68 61 51 57 ...
 $ dmin     : num  3.49 2.38 5.81 1.18 6.32 ...
 $ rms      : num  1.13 1.18 0.62 1.36 0.87 0.97 1.06 0.94 0.92 0.73 ...
 $ net      : chr  "us" "us" "us" "us" ...
 $ id       : chr  "usb000px6z" "usb000px6r" "usb000px5z" "usb000pwvh" ...
 $ updated  : chr  "2014-04-24T06:08:38.456Z" "2014-04-24T08:36:51.121Z" "2014-04-24T02:33:25.699Z" "2014-
04-24T06:27:47.745Z" ...
 $ place    : chr  "95km S of Port Hardy, Canada" "94km S of Port Hardy, Canada" "20km SW of Lata, Solomon
Islands" "93km S of Naze, Japan" ...
 $ type     : chr  "earthquake" "earthquake" "earthquake" "earthquake" ...
 $ date     : Date, format: "2014-04-24" "2014-04-24" "2014-04-24" "2014-04-23" ...
 $ year     : num  2014 2014 2014 2014 2014 ...
```

```
library(squash)
attach(catalog)

# the color in the squashgram indicates a summary (in this case the mean) of all z values
# of the points falling into the bin

squashgram(depth ~ longitude + latitude, FUN=mean,main = "Depth of earthquakes (2004-2014)")
```




```
# a larger quare indicates more points faling into the rectangular interval

squashgram(depth ~ longitude + latitude, FUN=mean, shrink=10,main = "Depth of earthquakes
                (2004-2014)")
```



```
# Example 20
# Dot density maps in R
# choropleth maps are useful to show values for areas on a map, but they can be limited
# dot density maps are sometimes better for showing distributions within regions

# www.flowingdata.com
# create a dot density map for population in California
# source : American Community Survey at the census tract level

setwd("c:/R/Rdata/DDM")

# California population data
acsClasses <- c("character","character","character","numeric","numeric")
calipop <- read.csv("ACS_12_5YR_B01003_with_ann_CA.csv",
                    stringsAsFactors=FALSE,colClasses=acsClasses,sep=",")
str(calipop)
```

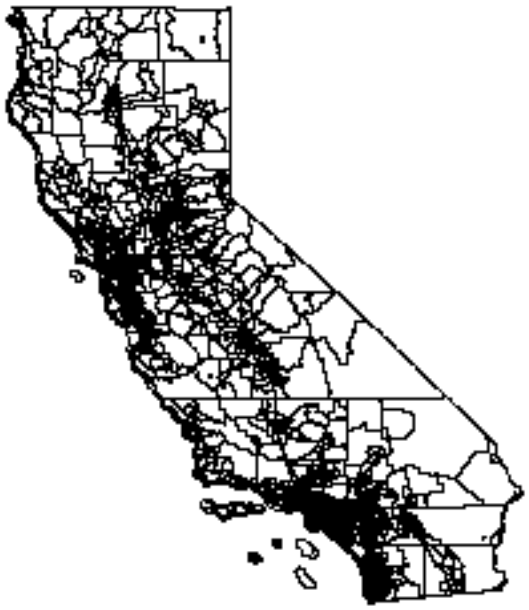
```
> str(calipop)
'data.frame':       8057 obs. of  5 variables:
 $ geoid     : chr  "1400000US06001400100" "1400000US06001400200" "1400000US06001400300"
"1400000US06001400400" ...
 $ geoid2    : chr  "06001400100" "06001400200" "06001400300" "06001400400" ...
 $ geoname   : chr  "Census Tract 4001, Alameda County, California" "Census Tract 4002,
Alameda County, California" "Census Tract 4003, Alameda County, California" "Census Tract
4004, Alameda County, California" ...
 $ totalpop  : num  2587 1981 5246 4222 3573 ...
 $ maroferror: num  196 122 544 453 262 256 443 368 369 475 ...
```

```
# we only need 2 colums : the census tract geographic id to link with shapefile data and
# population estimate
calipop.sub <- calipop[,c(2,4)]
head(calipop.sub)
str(calipop.sub)
```

```
> head(calipop.sub)
       geoid2 totalpop
1 06001400100     2587
2 06001400200     1981
3 06001400300     5246
4 06001400400     4222
5 06001400500     3573
6 06001400600     1767
> str(calipop.sub)
'data.frame':       8057 obs. of  2 variables:
 $ geoid2  : chr  "06001400100" "06001400200" "06001400300" "06001400400" ...
 $ totalpop: num  2587 1981 5246 4222 3573 ...
```

```
# California shapefile for census tracts
library(maptools)
catract.shp <- readShapePoly("tl_2012_06_tract.shp",proj4string=CRS("+proj=longlat"))
class(catract.shp)
capolys <- SpatialPolygonsDataFrame(catract.shp,data=as(catract.shp,"data.frame"))
class(capolys)
summary(capolys)
str(capolys@data)
head(capolys@data)
plot(capolys)
```

```
> str(capolys@data)
'data.frame':        8057 obs. of  12 variables:
 $ STATEFP : Factor w/ 1 level "06": 1 1 1 1 1 1 1 1 1 1 ...
 $ COUNTYFP: Factor w/ 58 levels "001","003","005",..: 42 42 42 42 24 24 24 24 24 ...
 $ TRACTCE : Factor w/ 6522 levels "000100","000101",..: 196 194 153 30 31 237 238 145 86 100 ...
 $ GEOID   : Factor w/ 8057 levels "06001400100",..: 6876 6874 6859 6839 6840 3667 3668 3654 3642 3644 ...
 $ NAME    : Factor w/ 6522 levels "1","1.01","1.02",..: 1352 1350 975 2322 2323 1849 1850 842 6091 22 ...
 $ NAMELSAD: Factor w/ 6522 levels "Census Tract 1",..: 1352 1350 975 2322 2323 1849 1850 842 6091 22 ...
 $ MTFCC   : Factor w/ 1 level "G5020": 1 1 1 1 1 1 1 1 1 1 ...
 $ FUNCSTAT: Factor w/ 1 level "S": 1 1 1 1 1 1 1 1 1 1 ...
 $ ALAND   : num  7220755 18383574 4225135 509990 1021116 ...
 $ AWATER  : num  15488 142484 0 0 0 ...
 $ INTPTLAT: Factor w/ 8057 levels "+32.5473763",..: 4651 4655 4391 4431 4438 5362 5366 5494 5395 5607 ...
 $ INTPTLON: Factor w/ 8055 levels "-114.3064842",..: 5222 5210 4836 4921 4935 5361 5334 5236 5251 5229 ...
 - attr(*, "data_types")= chr  "C" "C" "C" "C" ...
```



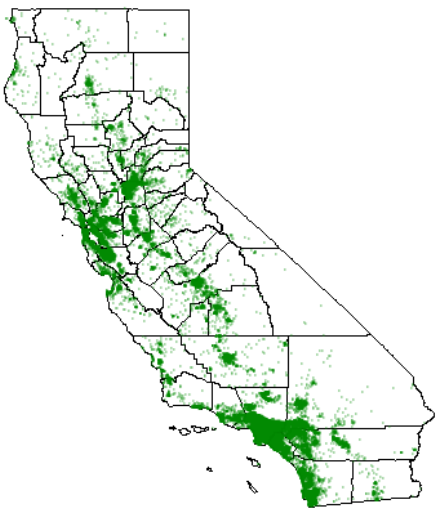
# merge datasets
cadata <- merge(capolys@data,calipop.sub,by.x="GEOID",by.y="geoid2",sort=FALSE)
str(cadata)
head(cadata)

```
> str(cadata)
'data.frame':        8057 obs. of  13 variables:
 $ GEOID   : Factor w/ 8057 levels "06001400100",..: 6876 6874 6859 6839 6840 3667 3668 3654 3642 3644 ...
 $ STATEFP : Factor w/ 1 level "06": 1 1 1 1 1 1 1 1 1 1 ...
 $ COUNTYFP: Factor w/ 58 levels "001","003","005",..: 42 42 42 42 24 24 24 24 24 ...
 $ TRACTCE : Factor w/ 6522 levels "000100","000101",..: 196 194 153 30 31 237 238 145 86 100 ...
 $ NAME    : Factor w/ 6522 levels "1","1.01","1.02",..: 1352 1350 975 2322 2323 1849 1850 842 6091 22 ...
 $ NAMELSAD: Factor w/ 6522 levels "Census Tract 1",..: 1352 1350 975 2322 2323 1849 1850 842 6091 22 ...
 $ MTFCC   : Factor w/ 1 level "G5020": 1 1 1 1 1 1 1 1 1 1 ...
 $ FUNCSTAT: Factor w/ 1 level "S": 1 1 1 1 1 1 1 1 1 1 ...
 $ ALAND   : num  7220755 18383574 4225135 509990 1021116 ...
 $ AWATER  : num  15488 142484 0 0 0 ...
 $ INTPTLAT: Factor w/ 8057 levels "+32.5473763",..: 4651 4655 4391 4431 4438 5362 5366 5494 5395 5607 ...
 $ INTPTLON: Factor w/ 8055 levels "-114.3064842",..: 5222 5210 4836 4921 4935 5361 5334 5236 5251 5229 ...
 $ totalpop: num  3002 4885 4917 3040 4310 ...
> head(cadata)
      GEOID STATEFP COUNTYFP TRACTCE  NAME          NAMELSAD MTFCC FUNCSTAT    ALAND AWATER    INTPTLAT     INTPTLON totalpop
1 06083002013      06      083  002013 20.13 Census Tract 20.13 G5020        S  7220755  15488 +34.8835980 -120.4779852     3002
2 06083002011      06      083  002011 20.11 Census Tract 20.11 G5020        S 18383574 142484 +34.9053343 -120.4616815     4885
3 06083001601      06      083  001601 16.01 Census Tract 16.01 G5020        S  4225135      0 +34.4052646 -119.5173821     4917
4 06083000301      06      083  000301  3.01  Census Tract 3.01 G5020        S   509990      0 +34.4261948 -119.7150662     3040
5 06083000302      06      083  000302  3.02  Census Tract 3.02 G5020        S  1021116      0 +34.4309086 -119.7222979     4310
6 06047002301      06      047  002301 23.01 Census Tract 23.01 G5020        S  8081536      0 +37.0496090 -120.8635648     6477
```

```
# we will make a dot density map of "totalpop" and define one dot per 1000 people
plotvar <- cadata$totalpop/1000
# the hard part of making dot density maps is figuring out where to put the dots
# and how many of them to draw
# the dotsInPolys() function from the maptools package does most of the work
# the first argument provides the polygons, the second provides the estimate for each polygon
# and the last argument says how to draw the dots within each polygon

# generate randon dots in polygons (census tracts)
cadots.rand <- dotsInPolys(capolys,as.integer(plotvar),f="random")
str(cadots.rand)
```

```
> str(cadots.rand)
Formal class 'SpatialPointsDataFrame' [package "sp"] with 5 slots
  ..@ data       :'data.frame':       33344 obs. of  1 variable:
  .. ..$ ID: Factor w/ 7930 levels "0","1","100",..: 1 1 1 2 2 2 2 1095 1095 1095 ...
  ..@ coords.nrs : int [1:2] 1 2
  ..@ coords     : num [1:33344, 1:2] -120 -120 -120 -120 -120 ...
  .. ..- attr(*, "dimnames")=List of 2
  .. .. ..$ : NULL
  .. .. ..$ : chr [1:2] "x" "y"
  ..@ bbox       : num [1:2, 1:2] -124.3 32.5 -114.4 42
  .. ..- attr(*, "dimnames")=List of 2
  .. .. ..$ : chr [1:2] "x" "y"
  .. .. ..$ : chr [1:2] "min" "max"
  ..@ proj4string:Formal class 'CRS' [package "sp"] with 1 slots
  .. .. ..@ projargs: chr NA
```

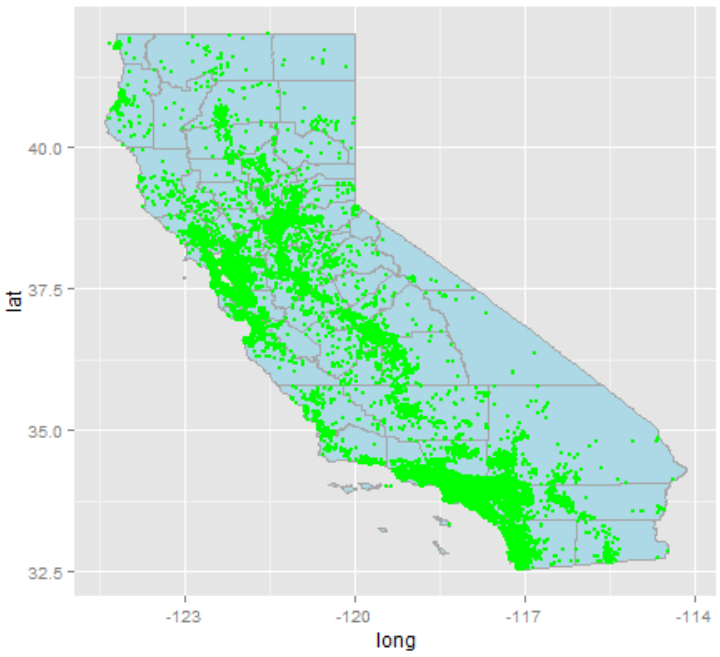
```
# map the dots
# even though we calculated dots based on tract-level data, we draw county lines
# drawing the tracts (there are a lot of them) would clutter the map
# so we load the county shapefile
cacounties.shp <- readShapePoly("california_county_shape_file.shp",
                                proj4string=CRS("+proj=longlat"))
cacounties <- SpatialPolygonsDataFrame(cacounties.shp,data=as(cacounties.shp,"data.frame"))

# now we can plot the counties and draw the dots on top of the existing county map
par(mar=c(0,0,0,0))
plot(cacounties,lwd=0.1)
plot(cadots.rand,add=TRUE,pch=19,cex=0.1,col="#00880030")
```



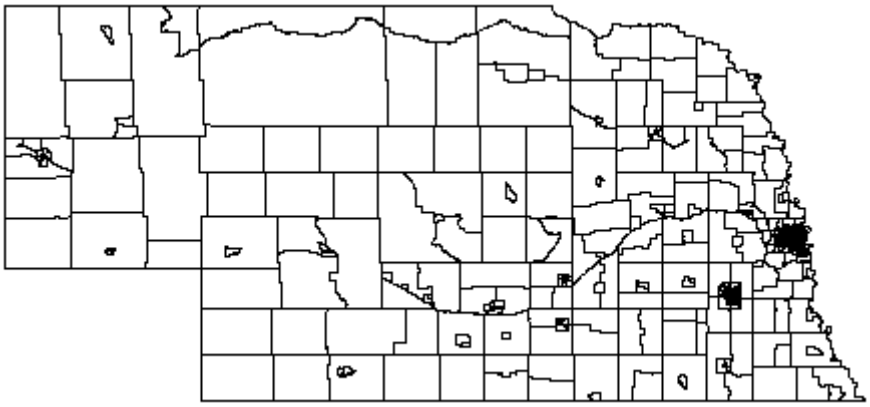
```
# dot density map with ggplot2

library(ggplot2)
cashape <- fortify(cacounties)

map <- ggplot(cashape,aes(x=long,y=lat)) +
geom_polygon(aes(group=group),color=I("grey65"),fill="lightblue") + coord_equal()
map

df <- data.frame(coordinates(cadots.rand)[,1:2])
str(df)
```

```
> str(df)
'data.frame':       33344 obs. of  2 variables:
 $ x: num  -120 -120 -120 -120 -120 ...
 $ y: num  34.9 34.9 34.9 34.9 34.9 ...
```

```
map <- map + geom_point(data=df,aes(x=x,y=y),color="green",size=0.01)
map
```



```
# let's try the same with a different state : Nebraska

nepop <- read.csv("ACS_12_5YR_B01003_with_ann.csv",
                  stringsAsFactors=FALSE,colClasses=acsClasses,sep=",")
str(nepop)

# we only need 2 colums : the census tract geographic id to link with shapefile data and
# population estimate
nepop.sub <- nepop[,c(2,4)]
head(nepop.sub)
str(nepop.sub)
# Nebraska shapefile for census tracts
netract.shp <- readShapePoly("tl_2013_31_tract.shp",proj4string=CRS("+proj=longlat"))
class(netract.shp)
nepolys <- SpatialPolygonsDataFrame(netract.shp,data=as(netract.shp,"data.frame"))
class(nepolys)
summary(nepolys)
str(nepolys@data)
head(nepolys@data)
plot(nepolys)
```



```
# merge datasets
nedata <- merge(nepolys@data,nepop.sub,by.x="GEOID",by.y="geoid2",sort=FALSE)
str(nedata)
head(nedata)
```

```
> head(nedata)
        GEOID STATEFP COUNTYFP TRACTCE   NAME             NAMELSAD MTFCC FUNCSTAT      ALAND   AWATER    INTPTLAT      INTPTLON totalpop
1 31107976300      31      107  976300   9763   Census Tract 9763 G5020        S  531437401    73600 +42.5171718 -097.6672886     2406
2 31107976200      31      107  976200   9762   Census Tract 9762 G5020        S 1281360702 18219964 +42.6043409 -098.1101770     3112
3 31047968500      31      047  968500   9685   Census Tract 9685 G5020        S    9883984    16592 +40.7879777 -099.7260672     5505
4 31047968100      31      047  968100   9681   Census Tract 9681 G5020        S  667954449   732690 +40.9406999 -099.9617161     1672
5 31177050202      31      177  050202 502.02 Census Tract 502.02 G5020        S  140354172  4321210 +41.4470615 -096.0175528     2933
6 31177050102      31      177  050102 501.02 Census Tract 501.02 G5020        S   42444565  1048143 +41.5525629 -096.1192262     5206
```

```
# we will make a dot density map of "totalpop" and define one dot per 1000 people
plotvar <- nedata$totalpop/100
```

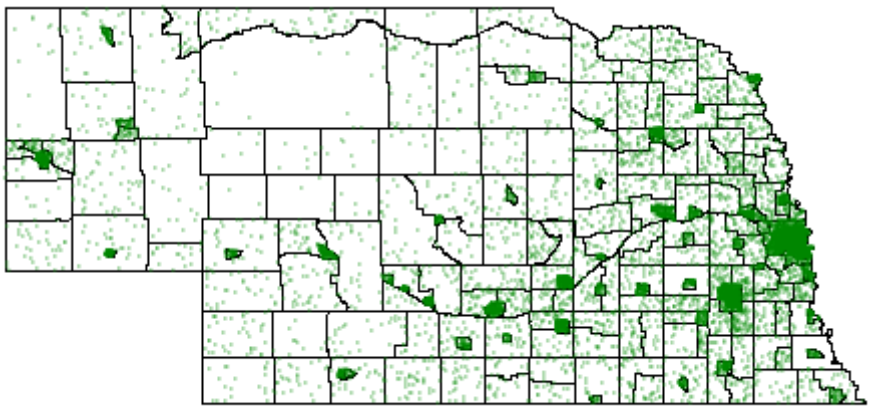
# generate randon dots in polygons (census tracts)
nedots.rand <- dotsInPolys(nepolys,as.integer(plotvar),f="random")
str(nedots.rand)

```
> str(nedots.rand)
Formal class 'SpatialPointsDataFrame' [package "sp"] with 5 slots
  ..@ data       :'data.frame':       17937 obs. of  1 variable:
  .. ..$ ID: Factor w/ 530 levels "0","1","10","100",..: 1 1 1 1 1 1 1 1 1 1 ...
  ..@ coords.nrs : int [1:2] 1 2
  ..@ coords     : num [1:17937, 1:2] -97.5 -97.8 -97.7 -97.5 -97.7 ...
  .. ..- attr(*, "dimnames")=List of 2
  .. .. ..$ : NULL
  .. .. ..$ : chr [1:2] "x" "y"
  ..@ bbox       : num [1:2, 1:2] -104.1 40 -95.3 43
  .. ..- attr(*, "dimnames")=List of 2
  .. .. ..$ : chr [1:2] "x" "y"
  .. .. ..$ : chr [1:2] "min" "max"
  ..@ proj4string:Formal class 'CRS' [package "sp"] with 1 slots
  .. .. ..@ projargs: chr NA
```

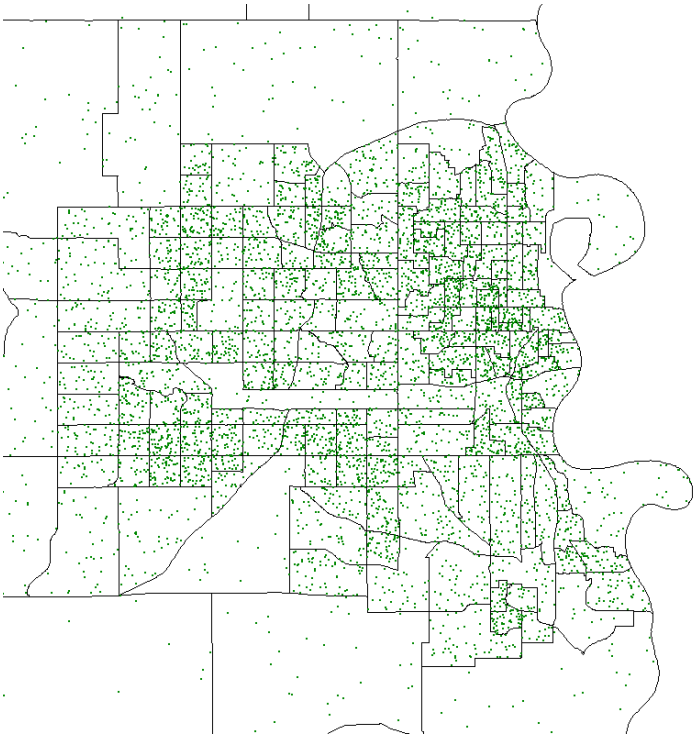
nedots.rand@coords

```
 [4986,]  -95.97476 41.26038
 [4987,]  -95.98364 41.26873
 [4988,]  -95.96690 41.27020
 [4989,]  -95.96925 41.27043
 [4990,]  -95.97669 41.26846
 [4991,]  -95.97798 41.26957
 [4992,]  -95.97640 41.25984
 [4993,]  -95.97307 41.27306
 [4994,]  -95.97087 41.27088
 [4995,]  -95.97807 41.26426
 [4996,]  -95.98144 41.27264
 [4997,]  -95.97713 41.26124
 [4998,]  -95.98404 41.26427
 [4999,]  -95.97737 41.26723
 [5000,]  -95.98085 41.26839
 [ reached getOption("max.print") -- omitted 12937 rows ]
```

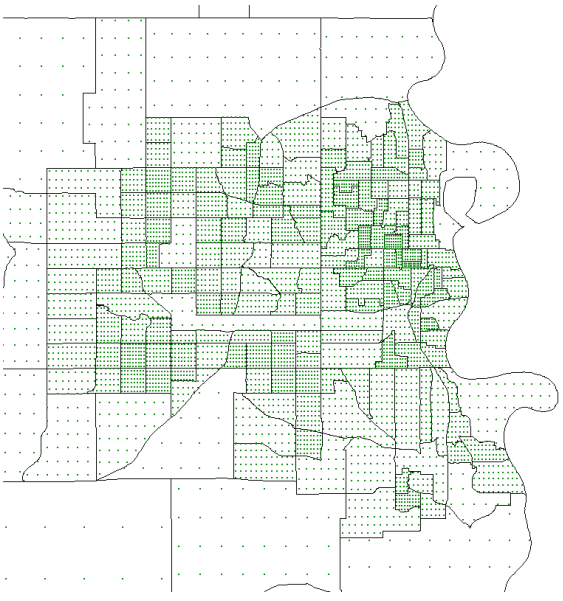
# now we can plot the counties and draw the dots on top of the existing county map
par(mar=c(0,0,0,0))
plot(nepolys,lwd=0.1)
plot(nedots.rand,add=TRUE,pch=19,cex=0.1,col="#00880030")



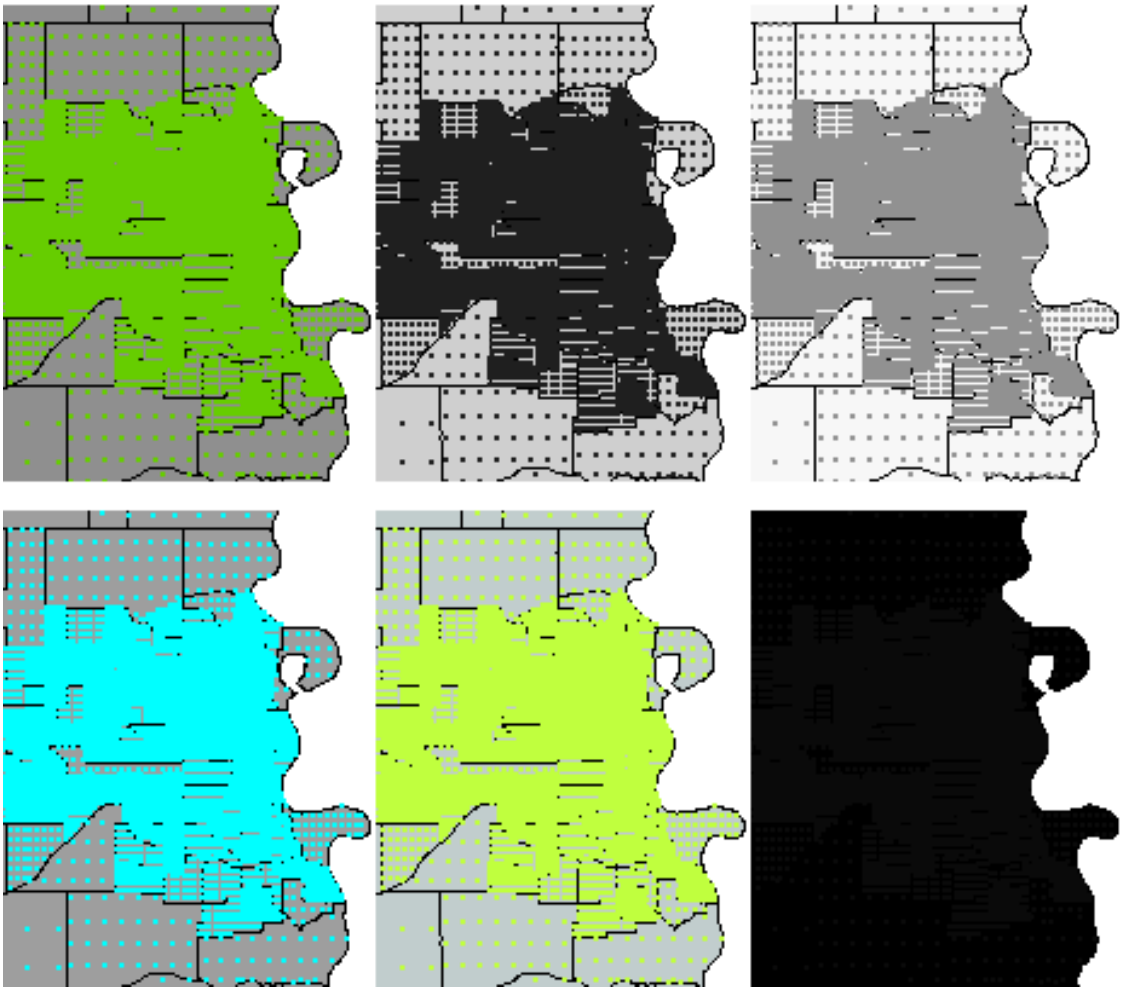
```
# in many parts of the state of Nebraska, the population is sparse
# therefore we will focus on a single area to see more than a blob of dots
# plot of a specific region (zoom on Omaha region)
plot(nepolys,lwd=0.1,xlim=c(-96.187303,-95.847993),ylim=c(41.073844,41.388218))
plot(nedots.rand,add=TRUE,pch=19,cex=0.1,col="#008800")
```



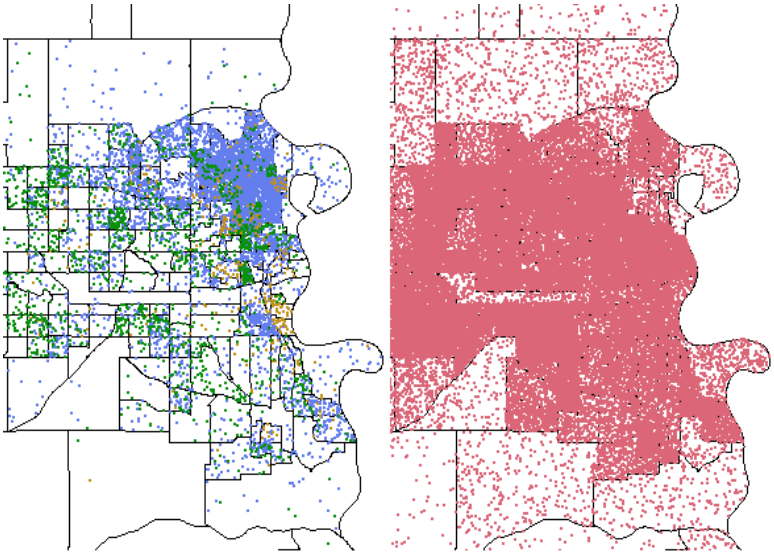
```
# grid of dots instead of random
nedots.reg <- dotsInPolys(nepolys, as.integer(plotvar), f="regular")
plot(nepolys, lwd=0.1, xlim=c(-96.187303,-95.847993), ylim=c(41.073844,41.388218))
plot(nedots.reg, add=TRUE, pch=19, cex=0.3, col="#008800")
```



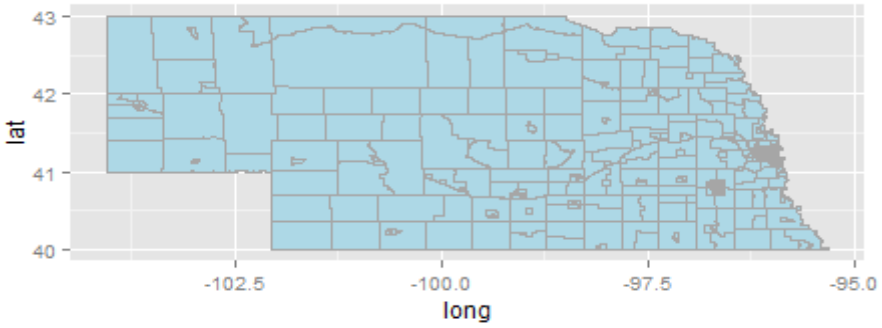
```
# color options
randomCols <- colors()[sample(1:502, 12)]
par(mfrow=c(2,3), mar=c(0,0,1,0))
for (i in 1:6) {
  plot(nepolys, lwd=0.1, xlim=c(-96.187303,-95.847993), ylim=c(41.073844,41.388218),
col=randomCols[i])
  plot(nedots.reg, add=TRUE, pch=19, cex=0.1, col=randomCols[6+i])
}
```



```
# using color to show another dimension
# we can color dots by category
# for example, for the state of Nebraska we have data of the population by race at the tract level

nerace <- read.csv("race-nebraska-truncated.csv",
                   stringsAsFactors=FALSE,
                   colClasses=c("character", "numeric", "numeric", "numeric", "numeric"))
nedata <- merge(nepolys@data, nerace, by.x="GEOID", by.y="geoid2", sort=FALSE)
races <- c("white", "black", "amind", "asian")
dotCols <- c("#da6678", "#647eee", "#c29219", "#09900d")
par(mar=c(0,0,0,0))
plot(nepolys, lwd=0.2, xlim=c(-96.187303,-95.847993), ylim=c(41.073844,41.388218))
for (i in 2:length(races)) {
  nevar <- nedata[,races[i]] / 10
  nedots.race <- dotsInPolys(nepolys, as.integer(nevar), f="random")
  plot(nedots.race, add=TRUE, pch=19, cex=0.01, col=dotCols[i])
}

# for whites only :
plot(nepolys, lwd=0.2, xlim=c(-96.187303,-95.847993), ylim=c(41.073844,41.388218))
for (i in 1:1) {
  nevar <- nedata[,races[i]] / 10
  nedots.race <- dotsInPolys(nepolys, as.integer(nevar), f="random")
  plot(nedots.race, add=TRUE, pch=19, cex=0.01, col=dotCols[i])
}
```



```
# dot density plot of race with ggplot 2

nemap <- fortify(nepolys)

map <- ggplot(nemap,aes(x=long,y=lat)) +
geom_polygon(aes(group=group),color=I("grey65"),fill="lightblue") + coord_equal()
map
```




```
str(nedata)
```

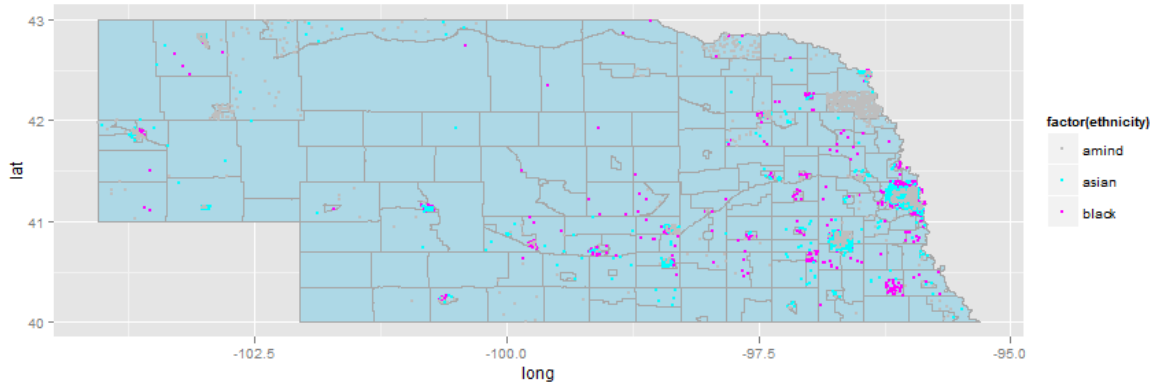
```
> str(nedata)
'data.frame':         532 obs. of  16 variables:
 $ GEOID   : Factor w/ 532 levels "31001965400",..: 306 305 77 73 522 520 523 521 519 72 ...
 $ STATEFP : Factor w/ 1 level "31": 1 1 1 1 1 1 1 1 1 1 ...
 $ COUNTYFP: Factor w/ 93 levels "001","003","005",..: 54 54 24 24 89 89 89 89 89 24 ...
 $ TRACTCE : Factor w/ 428 levels "000100","000200",..: 415 414 374 370 259 257 260 258 256 369 ...
 $ NAME    : Factor w/ 428 levels "1","10","10.01",..: 415 414 374 370 142 140 143 141 139 369 ...
 $ NAMELSAD: Factor w/ 428 levels "Census Tract 1",..: 415 414 374 370 142 140 143 141 139 369 ...
 $ MTFCC   : Factor w/ 1 level "G5020": 1 1 1 1 1 1 1 1 1 1 ...
 $ FUNCSTAT: Factor w/ 1 level "S": 1 1 1 1 1 1 1 1 1 1 ...
 $ ALAND   : num  5.31e+08 1.28e+09 9.88e+06 6.68e+08 1.40e+08 ...
 $ AWATER  : int  73600 18219964 16592 732690 4321210 1048143 1944971 1073365 0 6245826 ...
 $ INTPTLAT: Factor w/ 532 levels "+40.0325942",..: 521 523 106 180 434 446 445 436 441 162 ...
 $ INTPTLON: Factor w/ 532 levels "-095.5858870",..: 380 400 467 473 104 163 220 167 194 464 ...
 $ white   : num  2342 3049 3692 1528 2921 ...
 $ black   : num  1 8 488 0 10 52 0 12 26 31 ...
 $ amind   : num  30 31 29 0 0 12 8 4 11 32 ...
 $ asian   : num  8 0 0 11 0 7 3 0 36 29 ...
```

```
dots.bl <- dotsInPolys(nepolys,as.integer(nedata$black/10))
dots.bl$ethnicity <- "black"
dots.as <- dotsInPolys(nepolys,as.integer(nedata$asian/10))
dots.as$ethnicity <- "asian"
dots.am <- dotsInPolys(nepolys,as.integer(nedata$amind/10))
dots.am$ethnicity <- "amind"

# spRbind takes only two parameters at a time
dots.all <- spRbind(dots.bl,dots.as)
dots.all <- spRbind(dots.all,dots.am)
str(dots.all)
```

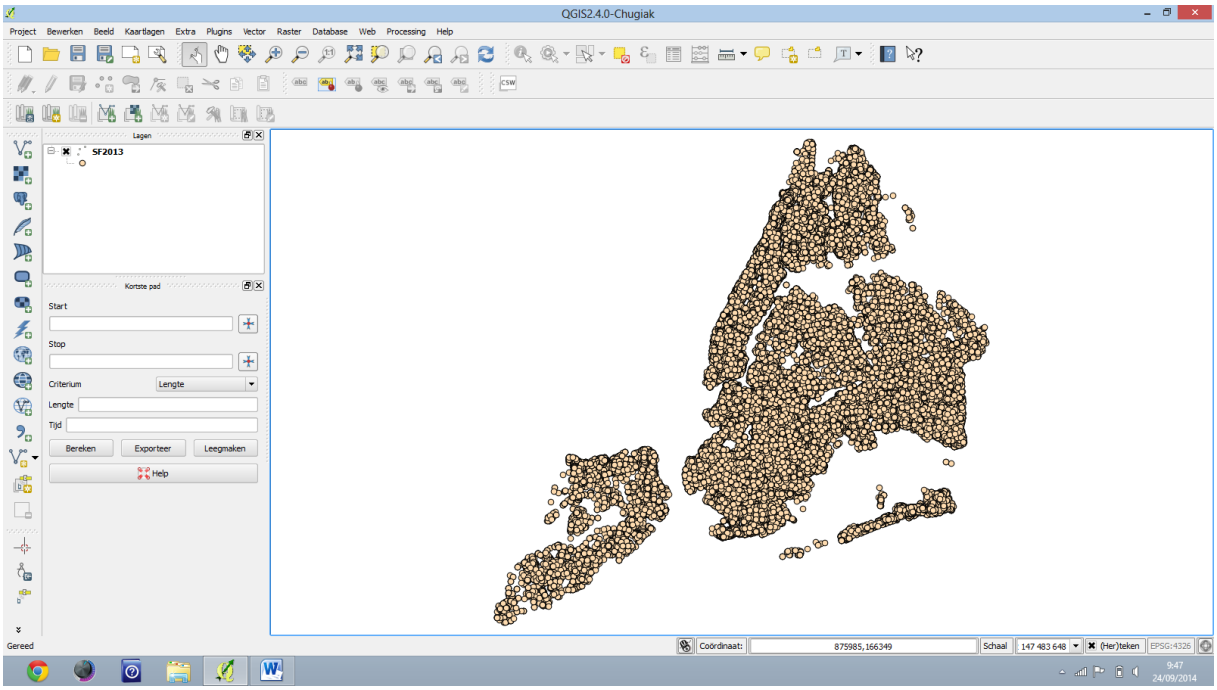
```
ethno.df <- data.frame(coordinates(dots.all)[,1:2],ethnicity=dots.all$ethnicity)
str(ethno.df)

df <- data.frame(coordinates(cadots.rand)[,1:2])
str(df)
```

```
> str(ethno.df)
'data.frame':	12628 obs. of  3 variables:
 $ x        : num  -99.7 -99.7 -99.7 -99.7 -99.7 ...
 $ y        : num  40.8 40.8 40.8 40.8 40.8 ...
 $ ethnicity: Factor w/ 3 levels "amind","asian",..: 3 3 3 3 3 3 3 3 3 3 ...
>
> df <- data.frame(coordinates(cadots.rand)[,1:2])
> str(df)
'data.frame':	33344 obs. of  2 variables:
 $ x: num  -120 -120 -120 -120 -120 ...
 $ y: num  34.9 34.9 34.9 34.9 34.9 ...
```

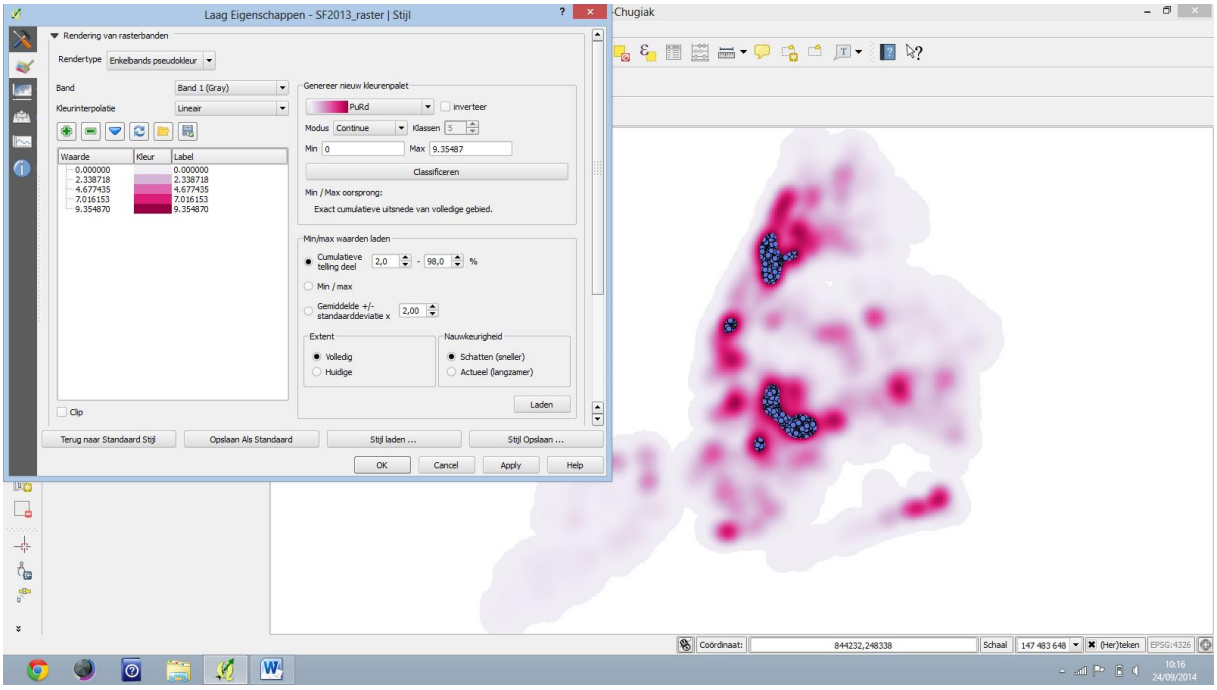
```
map <- map + geom_point(data=ethno.df,aes(x=x,y=y,colour=factor(ethnicity)),size=0.1) +
        scale_colour_manual(values=c("grey","cyan","magenta"))
map
```



Example 21
heatmap raster in QGis 2.4 and raster handling with ggplot2 in R
NY stop and frisk data, 2013

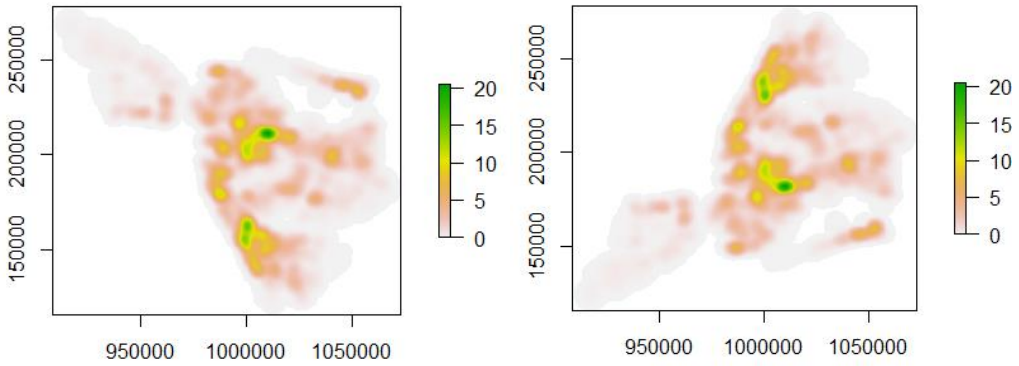


raster creation with heatmap plugin in QGis 2.4

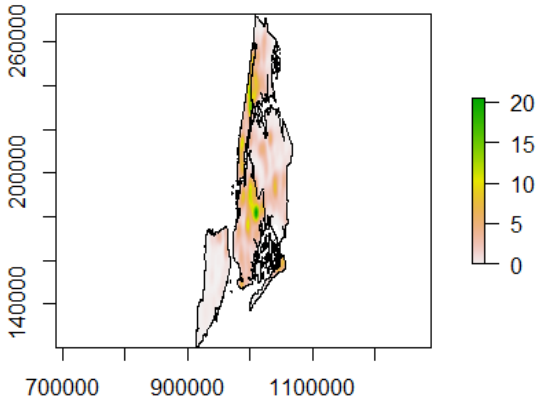


```
setwd("c:/R/Rdata/New_York")

library(raster)
library(maptools)
NYC <- readShapePoly("nybb.shp")
plot(NYC)
proj4string(NYC)
str(NYC@data)
class(NYC)
```

```
> str(NYC@data)
'data.frame':       5 obs. of  4 variables:
 $ BoroCode  : int  5 1 2 3 4
 $ BoroName  : Factor w/ 5 levels "Bronx","Brooklyn",..: 5 3 1 2 4
 $ Shape_Leng: num  330455 358397 464475 741229 896932
 $ Shape_Area: num  1.62e+09 6.36e+08 1.19e+09 1.94e+09 3.05e+09
 - attr(*, "data_types")= chr  "N" "C" "F" "F"
> class(NYC)
[1] "SpatialPolygonsDataFrame"
attr(,"package")
[1] "sp"
```




```
# crop and mask raster file
r2 <- crop(a,extent(NYC))
plot(r2)
r3 <- mask(r2,NYC)
plot(r3)
plot(NYC,add=TRUE,lwd=1)
```



```
# the best way to extract coordinates from a SPDF is to use ggplot2
library(ggplot2)
dum = fortify(NYC)
str(dum)
```

```
> str(dum)
'data.frame':	76086 obs. of  7 variables:
 $ long : num  961436 961461 961482 961533 961592 ...
 $ lat  : num  175473 175472 175483 175507 175525 ...
 $ order: int  1 2 3 4 5 6 7 8 9 10 ...
 $ hole : logi  FALSE FALSE FALSE FALSE FALSE FALSE ...
 $ piece: Factor w/ 31 levels "1","2","3","4",..: 1 1 1 1 1 1 1 1 1 1 ...
 $ group: Factor w/ 106 levels "0.1","0.2","0.3",..: 1 1 1 1 1 1 1 1 1 1 ...
 $ id   : chr  "0" "0" "0" "0" ...
```

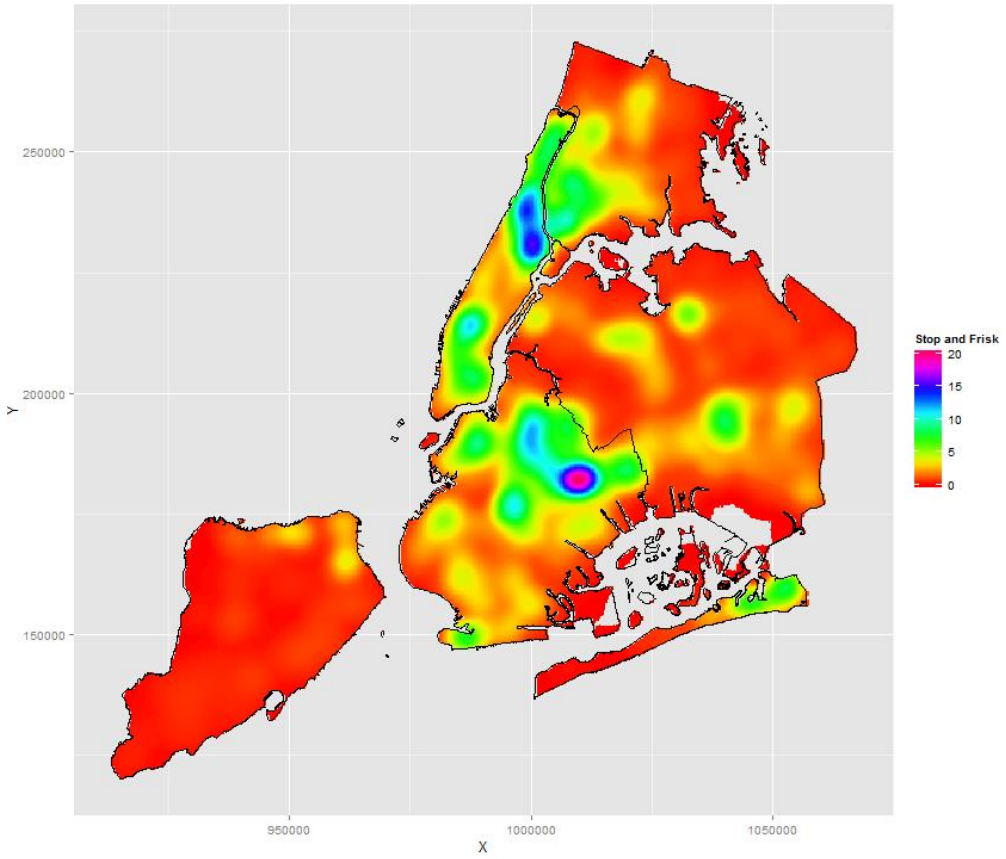
```
map <- ggplot(dum, aes(x = long, y = lat,group=group)) + geom_path()
map
```


```
# convert raster to dataframe
b <- rasterToPoints(r3)
df <- data.frame(b)
str(df)
```

```
> str(df)
'data.frame':	79250 obs. of  3 variables:
 $ x    : num  1009094 1009417 1009094 1009417 1009741 ...
 $ y    : num  272649 272649 272326 272326 272326 ...
 $ layer: num  0.0992 0.1093 0.1186 0.1294 0.1388 ...
```

```
colnames(df) <- c("X","Y","layer")
```

```
map <-  ggplot(df)+
       geom_raster(data=df,aes(X,Y,fill=layer))+
       scale_fill_gradientn(name="Stop and Frisk",colours = rainbow(20))
map

map + geom_path(data=dum,aes(x=long,y=lat,group=group)) +
    coord_equal()
```



```
# Example 22
# gathering tweets and plot longitude and latitude coordinates

# authentication in R (use R console)
> library(twitteR)
Loading required package: ROAuth
Loading required package: RCurl
Loading required package: bitops
Loading required package: digest
Loading required package: rjson
Warning messages:
1: package 'twitteR' was built under R version 3.0.2
2: package 'ROAuth' was built under R version 3.0.2
3: package 'RCurl' was built under R version 3.0.2
4: package 'rjson' was built under R version 3.0.3
> library(ROAuth)
> library(plyr)

Attaching package: 'plyr'

The following object is masked from 'package:twitteR':

    id

> library(stringr)
> library(ggplot2)
> library(RCurl)
> # Set SSL certs globally
> options(RCurlOptions = list(cainfo = system.file("CurlSSL", "cacert.pem", package = "RCurl")))
> reqURL <- "https://api.twitter.com/oauth/request_token"
> accessURL <- "https://api.twitter.com/oauth/access_token"
> authURL <- "https://api.twitter.com/oauth/authorize"
> apiKey <-  "hQTtYtA69EBF08J9iQlbR5j5q"
> apiSecret <- "P7R6LW3SGchaC9XDNOpnKu4Y2OEMwbbSSylVd8Ga5a4mSnU5SE"
> twitCred <- OAuthFactory$new(
+   consumerKey = apiKey,
+   consumerSecret = apiSecret,
+   requestURL = reqURL,
+   accessURL = accessURL,
+   authURL = authURL
+ )
> twitCred$handshake(
+   cainfo = system.file("CurlSSL", "cacert.pem", package = "RCurl")
+ )
To enable the connection, please direct your web browser to:
https://api.twitter.com/oauth/authorize?oauth_token=0Ds4zmXNK102B0J2yWv3ZMXZqvujJJ8p
When complete, record the PIN given to you and provide it here: 4447767
> registerTwitterOAuth(twitCred)
[1] TRUE
```

```
> searchTerm <- "#rstats"
> tweets <- searchTwitter(searchTerm,n=1000,cainfo="cacert.pem",lang="en")
> tweetFrame <- twListToDF(tweets)
```

```
> str(tweetFrame)
'data.frame':   1000 obs. of  16 variables:
 $ text          : chr  "Sometimes simplest answers are least obvious- interpolate less
frequent time series to frequency of the more frequent using ?ap"| __truncated__ "RT
@R_Programming: There are 37 Videos in this R Course, each dedicated to teach a New R Concept,
for Beginners. http://t.co/Ix"| __truncated__ "RT @seandavis12: Peter Humberg thorough
tutorial of \"Using knitr and pandoc to create reproducible scientific reports\" in #rs"|
__truncated__ "Plotting data sampled at different frequencies today- need to find a
reproducible way of solving this problem once and for all "| __truncated__ ...
 $ favorited     : logi  FALSE FALSE FALSE FALSE FALSE FALSE ...
 $ favoriteCount: num  0 0 0 0 0 0 0 0 1 0 ...
 $ replyToSN     : chr  NA NA NA NA ...
 $ created       : POSIXct, format: "2014-10-09 10:54:53" "2014-10-09 10:54:26" "2014-10-09
10:49:05" "2014-10-09 10:46:38" ...
 $ truncated     : logi  FALSE FALSE FALSE FALSE FALSE FALSE ...
 $ replyToSID    : chr  NA NA NA NA ...
 $ id            : chr  "520165496004829185" "520165384402399233" "520164038438031360"
"520163419685912576" ...
 $ replyToUID    : chr  NA NA NA NA ...
 $ statusSource : chr  "<a href=\"http://twitter.com\" rel=\"nofollow\">Twitter Web
Client</a>" "<a href=\"http://twitter.com\" rel=\"nofollow\">Twitter Web Client</a>" "<a
href=\"http://bufferapp.com\" rel=\"nofollow\">Buffer</a>" "<a href=\"http://twitter.com\"
rel=\"nofollow\">Twitter Web Client</a>" ...
 $ screenName    : chr  "DinosaurusGrace" "prabhakar_kuma" "asianturfgrass" "DinosaurusGrace"
...
 $ retweetCount : num  0 31 42 0 2 0 1 0 1 1 ...
 $ isRetweet     : logi  FALSE TRUE TRUE FALSE TRUE FALSE ...
 $ retweeted     : logi  FALSE FALSE FALSE FALSE FALSE FALSE ...
 $ longitude     : chr  NA NA NA NA ...
 $ latitude      : chr  NA NA NA NA ...
```

```
> write.csv(tweetFrame,file="c:/R/Rdata/tweetFrame1000.csv",row.names=FALSE)
> loc <- subset(tweetFrame,longitude > 0 | longitude < 0,select=c(longitude,latitude))
```

```
> str(loc)
'data.frame':   5 obs. of  2 variables:
 $ longitude: chr  "-75.1714254" "-71.11583637" "-79.57944531" "-75.17152154" ...
 $ latitude : chr  "40.02001327" "42.32943192" "43.69509127" "40.01993401" ...
```

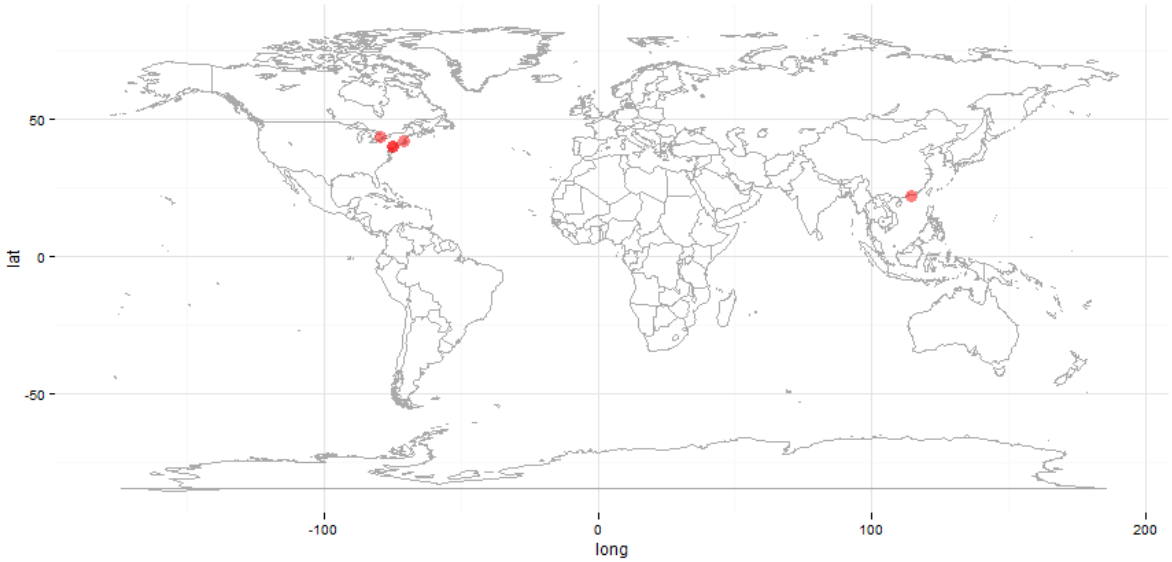
```
> write.csv(loc,file="c:/R/Rdata/tweetLocations.csv",row.names=FALSE)
```

```
> tweetLoc <- read.csv("tweetLocations.csv",header=T,sep=",")
```

```
> str(tweetLoc)
'data.frame':   5 obs. of  2 variables:
 $ longitude: num  -75.2 -71.1 -79.6 -75.2 114.2
 $ latitude : num  40 42.3 43.7 40 22.3
```

```
library(maps)
library(ggplot2)

worldMap <- map_data("world")  # Easiest way to grab a world map shapefile

zp1 <- ggplot(worldMap)
zp1 <- zp1 + geom_path(aes(x = long, y = lat, group = group), colour = gray(2/3), lwd = 1/3)
zp1
```

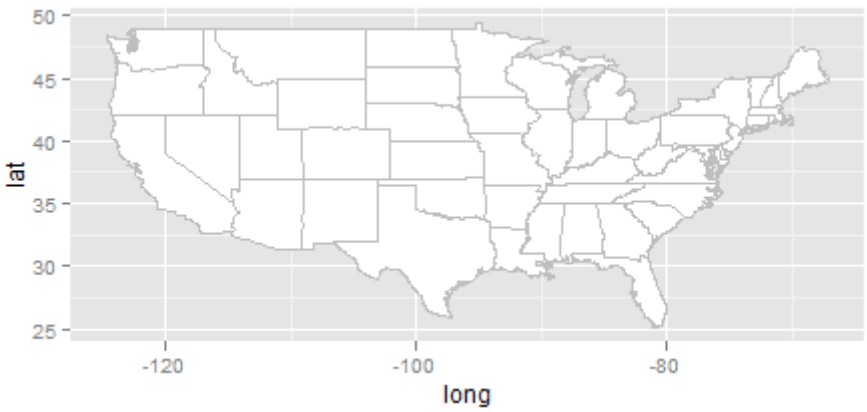
```
zp1 <- zp1 + geom_point(data = tweetLoc,  # Add points indicating users
                        aes(x = longitude, y = latitude),
                        colour = "RED", alpha = 1/2, size = 4)
zp1 <- zp1 + coord_equal()  # Better projections are left for a future post
zp1 <- zp1 + theme_minimal()  # Drop background annotations
zp1
```



```
# Example 23
# concentric circles as points in ggplot2 / ggmap

setwd("c:/R/Rdata")
concentric <- read.csv("concentric.csv",header=T,sep=";")
str(concentric)
head(concentric)
```

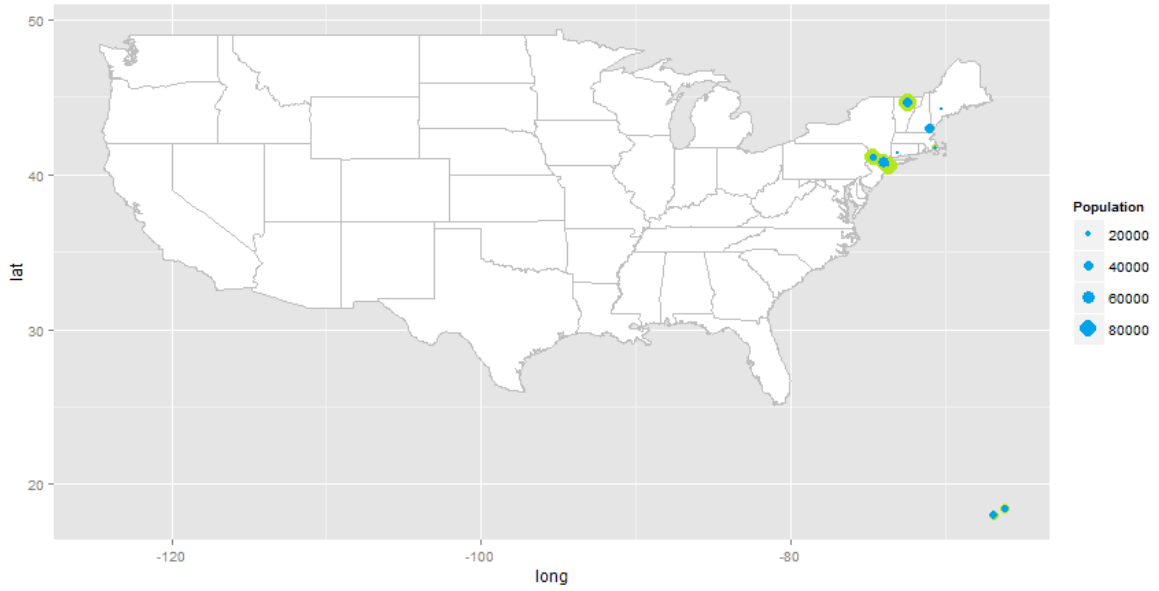
```
> head(concentric)
   zip        city state latitude longitude timezone   dst totalPop subPop
1  210  Portsmouth    NH 43.00590 -71.01320       -5  TRUE    43177  42705
2  653     Guanica    PR 17.99211 -66.90097       -4 FALSE    37224  36926
3  952 Sabana Seca    PR 18.42922 -66.18014       -4 FALSE    37168  27556
4 2571     Wareham    MA 41.75155 -70.71059       -5  TRUE    15492  10827
5 4211      Auburn    ME 44.19701 -70.23949       -5  TRUE     1614    774
6 5286  Craftsbury    VT 44.62770 -72.43440       -5  TRUE    88802  39060
```

```
library(ggplot)
library(ggmap)
library(maps)

# with ggplot2 :

all_states <- map_data("state")
str(all_states)
p <- ggplot()
p <- ggplot() +
geom_polygon(data=all_states,aes(x=long,y=lat,group=group),colour="grey",fill="white") +
 coord_equal()
p
```

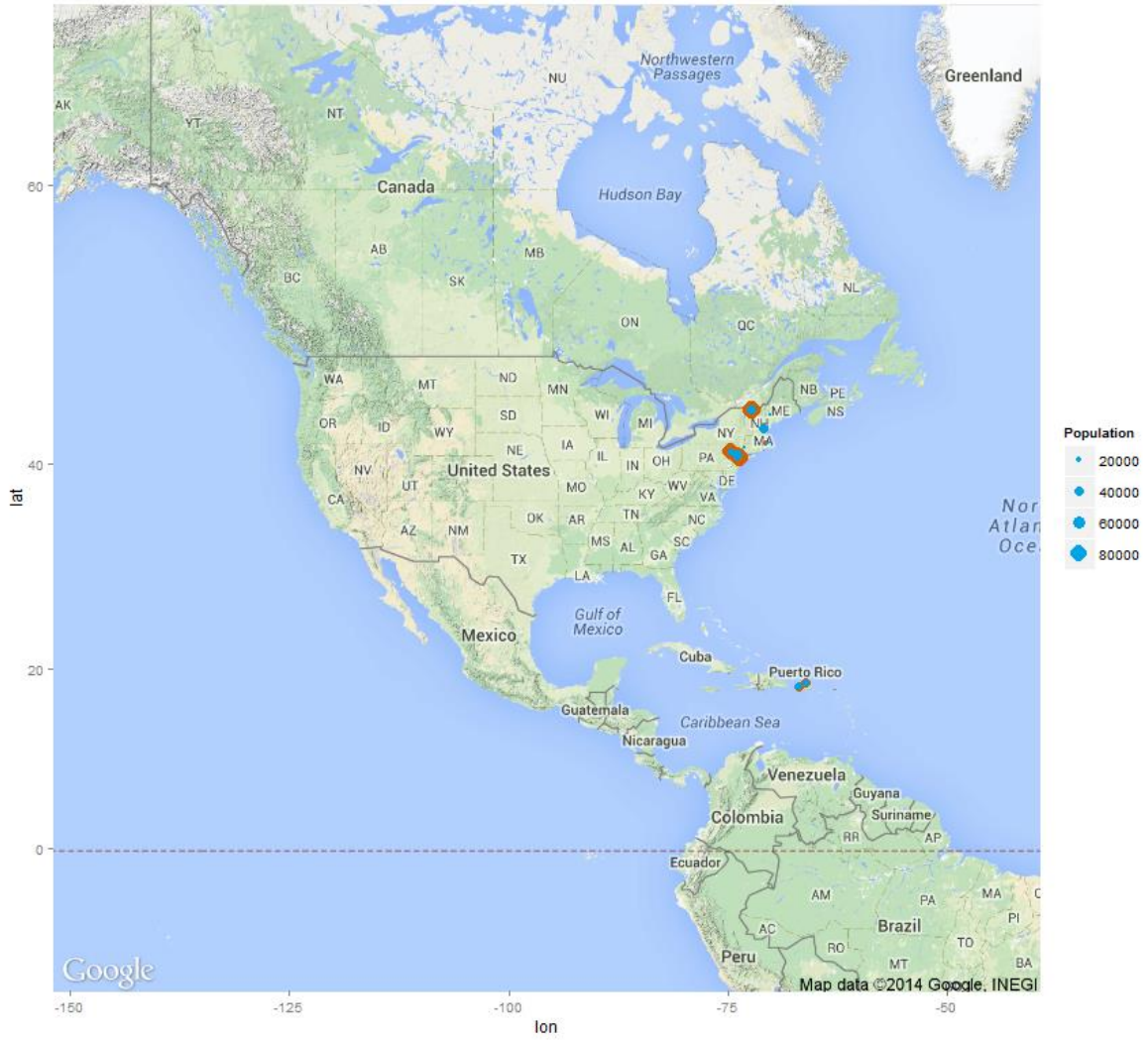



```
# the basic idea is to use separate geoms for two variables, making sure that the smaller one is
plotted
# after the larger one

# add total population
p <- p + geom_point(data=concentric,aes(x=longitude,y=latitude,size=totalPop),colour="#b5e521")
p
```

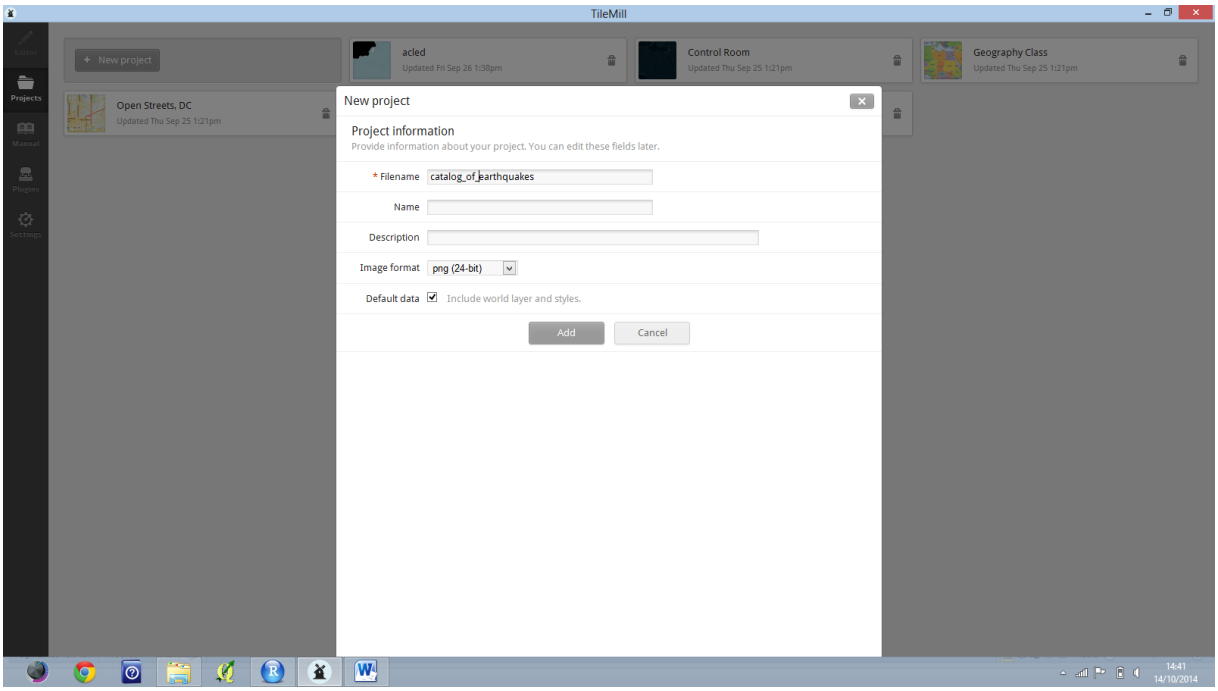
```
# add subpopulation
p <- p + geom_point(data=concentric,aes(x=longitude,y=latitude,size=subPop),colour="#00a3e8")
p

# change name of legend
p <- p + guides(size=guide_legend(title="Population"))
p
```

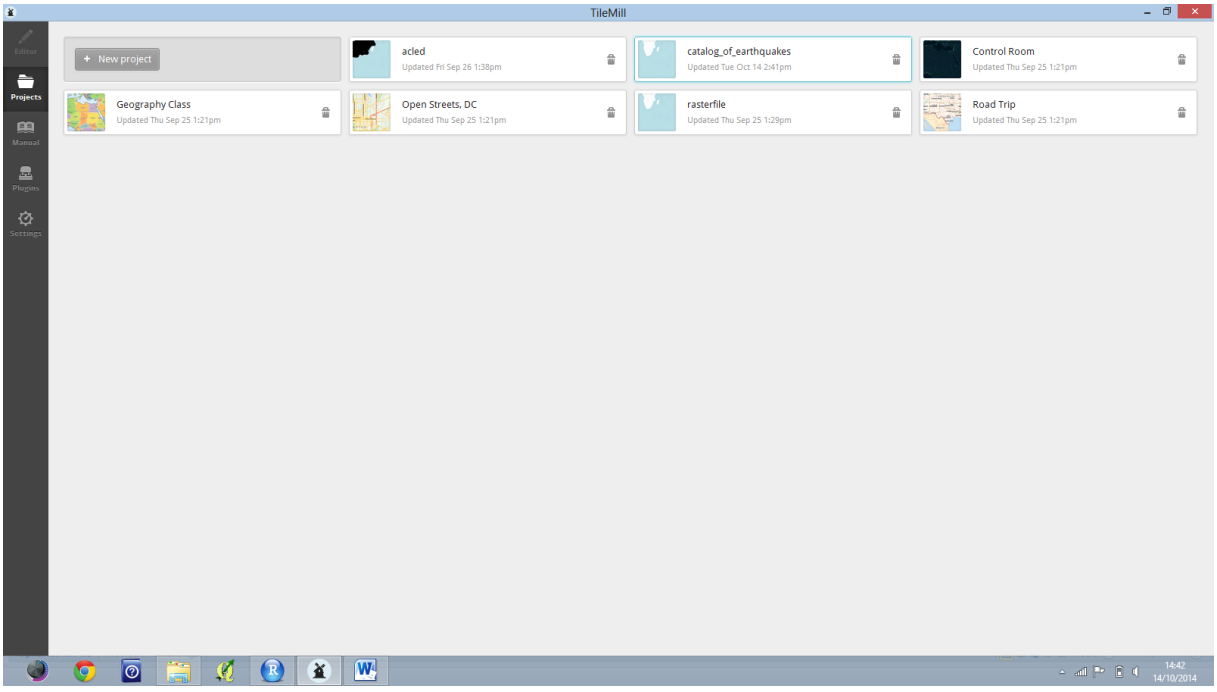


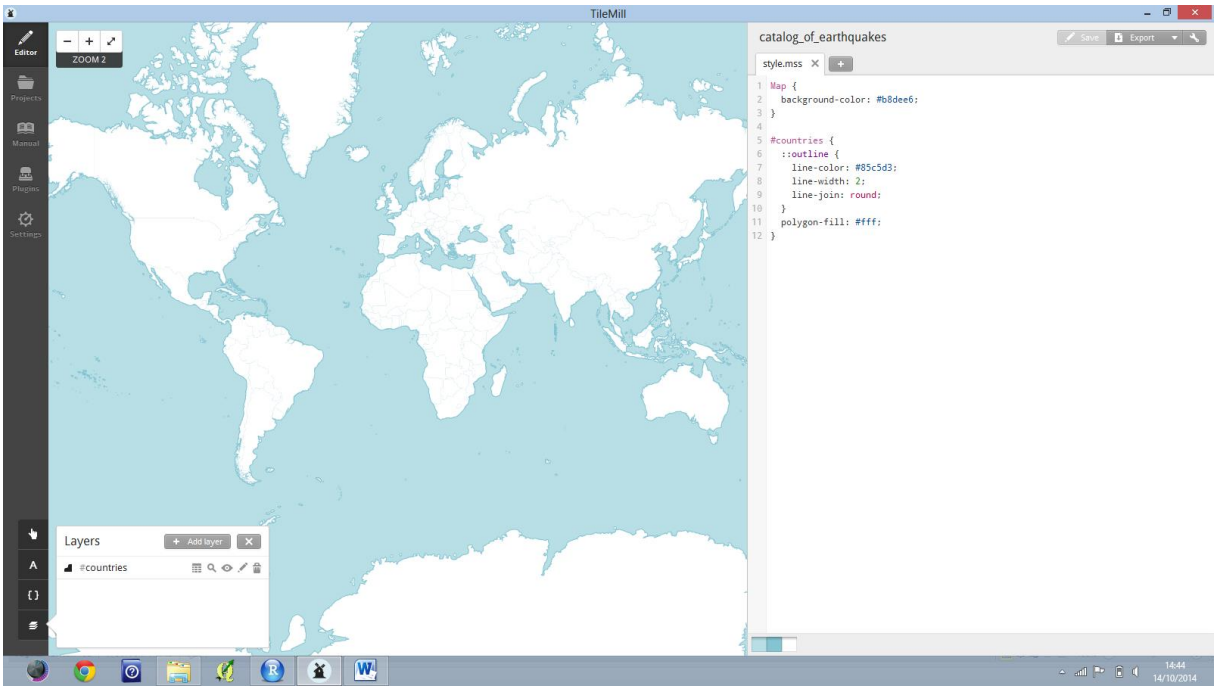

```
# with ggmap :

map <- get_map(location="united states",zoom=3,maptype="terrain",source="google")
p <- ggmap(map)
p

# add total population
p <- p + geom_point(data=concentric,aes(x=longitude,y=latitude,size=totalPop),colour="#D55E00")
p

# add subpopulation
p <- p + geom_point(data=concentric,aes(x=longitude,y=latitude,size=subPop),colour="#00a3e8")
p

# change name of legend
p <- p + guides(size=guide_legend(title="Population"))
p
```

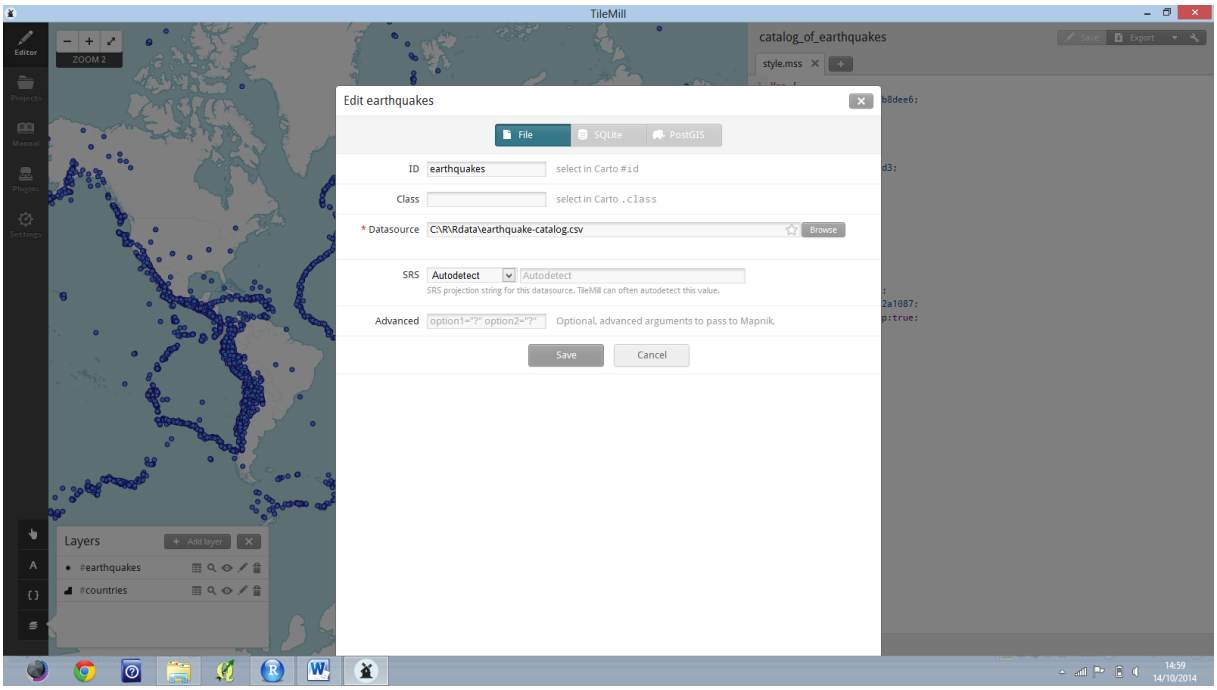

Northwestern Passages
Greenland
Canada
Hudson Bay
United States
Gulf of Mexico
Mexico
Cuba
Puerto Rico
Caribbean Sea
Guatemala
Nicaragua
Venezuela
Guyana
Suriname
Colombia
Ecuador
Brazil
Peru
Google
Map data ©2014 Google, INEGI
lat
lon
60
40
20
0
-150
-125
-100
-75
-50
Population
20000
40000
60000
80000

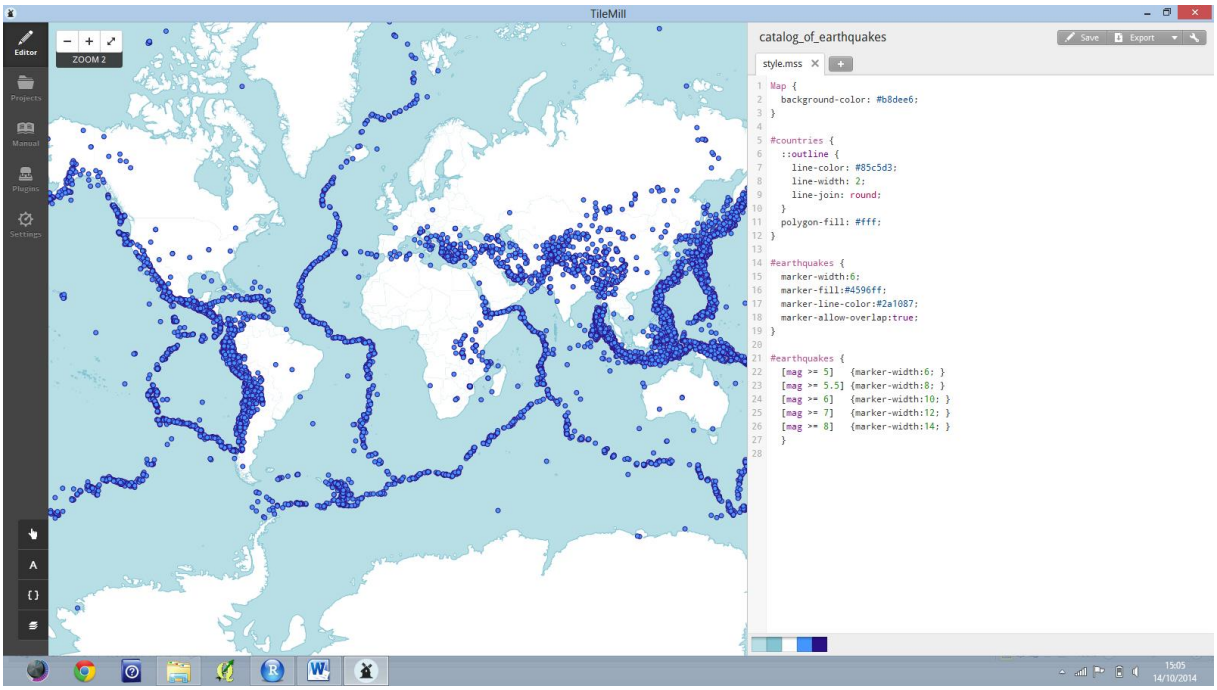
Example 24
import a csv-file in Tilemill and edit the data

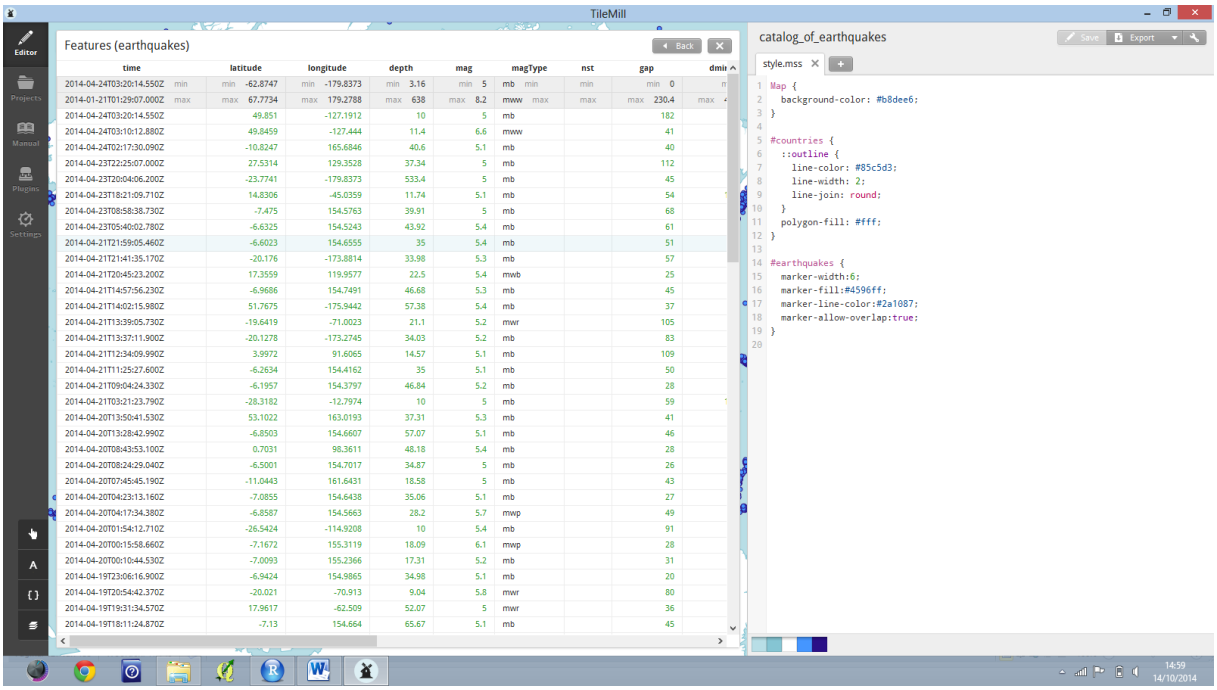


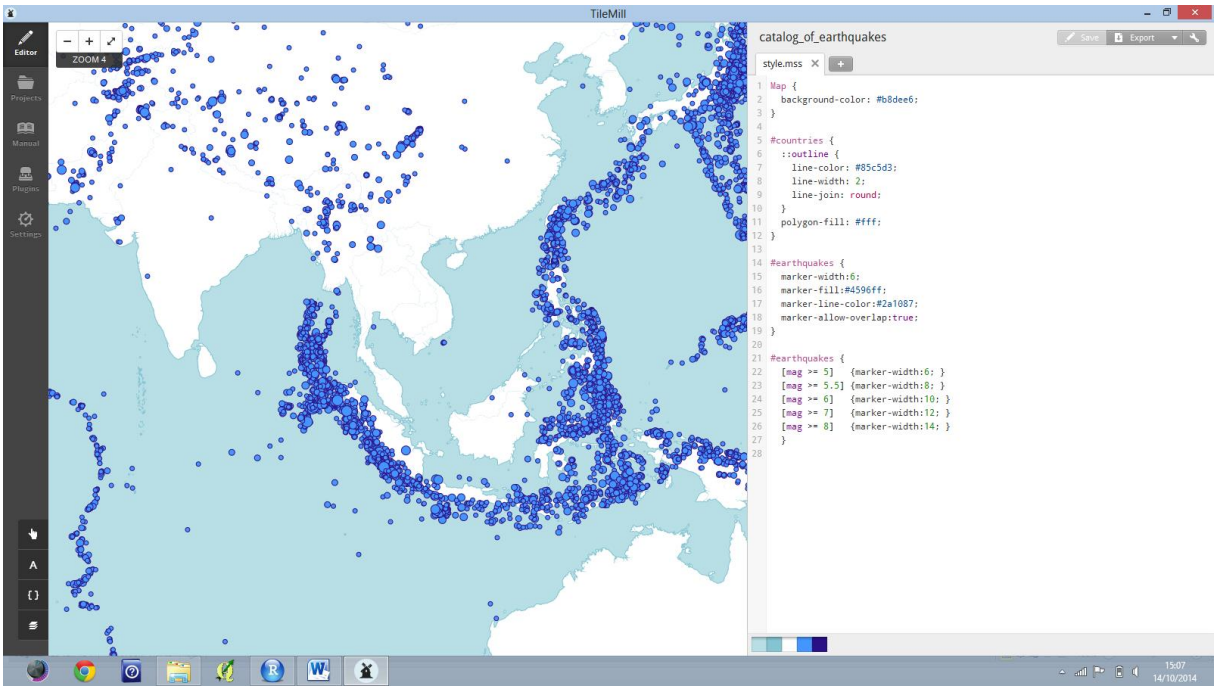


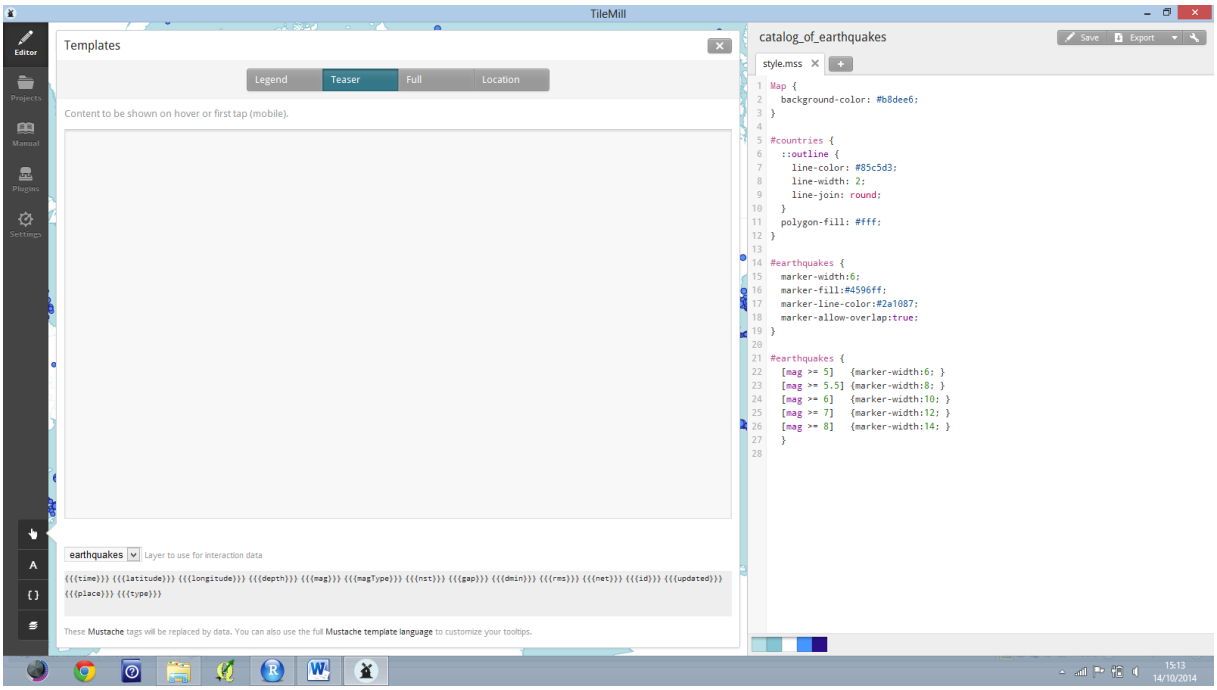

TileMill
ZOOM 2
catalog_of_earthquakes
style.mss
Map {
background-color: #b8dee6;
}
#countries {
::outline {
line-color: #85c5d3;
line-width: 2;
line-join: round;
}
polygon-fill: #fff;
}
Layers
Add layer
#countries

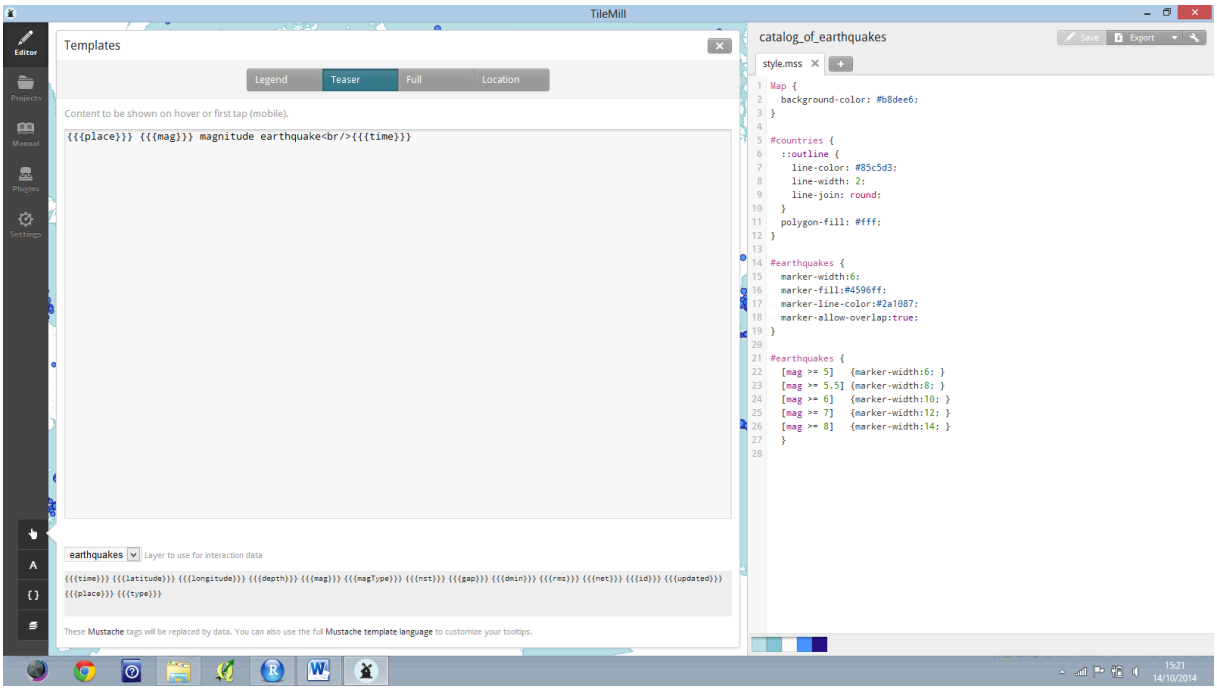

TileMill
ZOOM 2
catalog_of_earthquakes
style.mss
Edit earthquakes
File
SQLite
PostGIS
ID
earthquakes
select in Carto #id
Class
select in Carto .class
* Datasource
C:\R\Rdata\earthquake-catalog.csv
Browse
SRS
Autodetect
Autodetect
SRS projection string for this datasource. TileMill can often autodetect this value.
Advanced
option1="?" option2="?"
Optional, advanced arguments to pass to Mapnik.
Save
Cancel
Layers
Add layer
#earthquakes
#countries

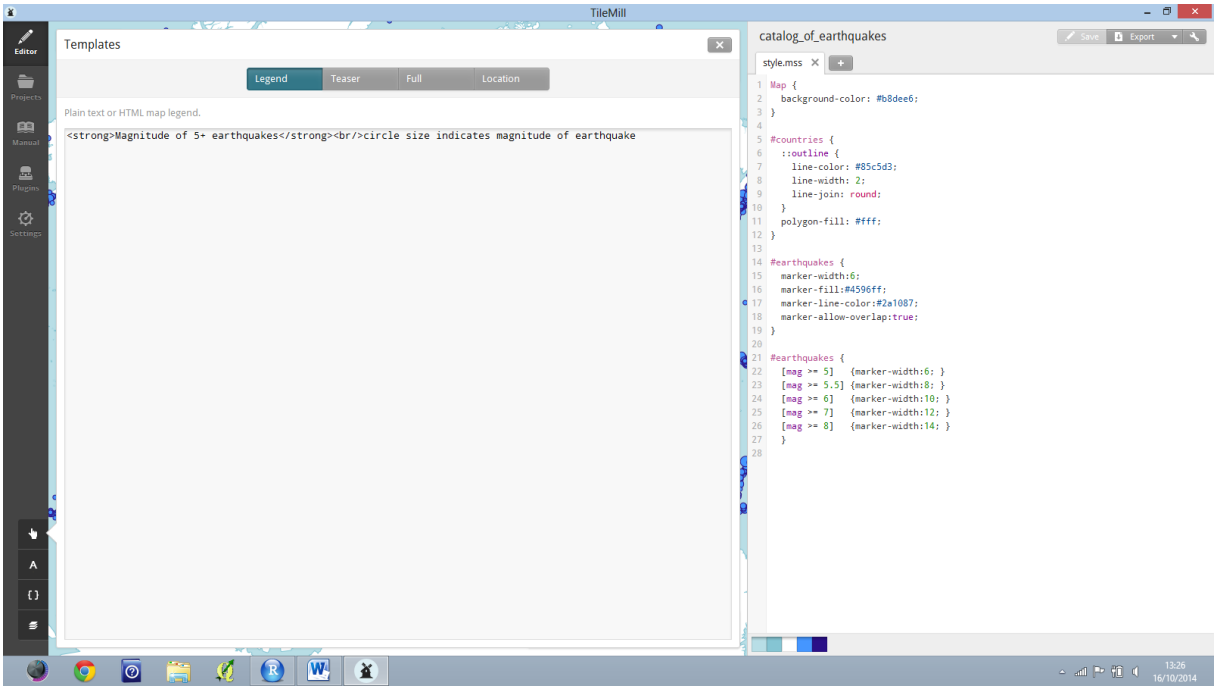

TileMill
Editor
Projects
Manual
Plugins
Settings
ZOOM 2
catalog_of_earthquakes
Save
Export
style.mss
Map {
background-color: #b8dee6;
}
#countries {
::outline {
line-color: #85c5d3;
line-width: 2;
line-join: round;
}
polygon-fill: #fff;
}
#earthquakes {
marker-width:6;
marker-fill:#4596ff;
marker-line-color:#2a1087;
marker-allow-overlap:true;
}
#earthquakes {
[mag >= 5] {marker-width:6; }
[mag >= 5.5] {marker-width:8; }
[mag >= 6] {marker-width:10; }
[mag >= 7] {marker-width:12; }
[mag >= 8] {marker-width:14; }
}

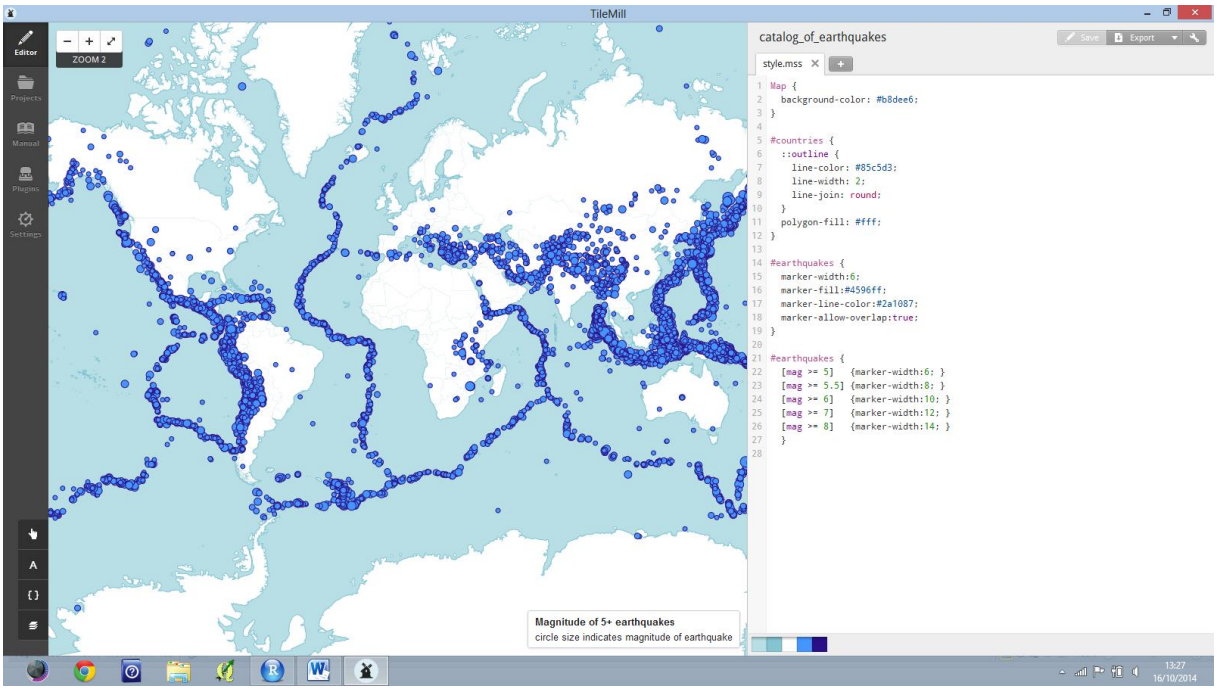

TileMill
Editor
Features (earthquakes)
Back
time latitude longitude depth mag magType nst gap
2014-04-24T03:20:14.550Z -62.8747 -179.8373 3.16 5 mb 0 230.4
2014-01-21T01:29:07.000Z 67.7734 179.2788 638 8.2 mww
2014-04-24T03:20:14.550Z 49.851 -127.1912 10 5 mb 182
2014-04-24T03:10:12.880Z 49.8459 -127.444 11.4 6.6 mww 41
2014-04-24T02:17:30.090Z -10.8247 165.6846 40.6 5.1 mb 40
2014-04-23T22:25:07.000Z 27.5314 129.3528 37.34 5 mb 112
2014-04-23T20:04:06.200Z -23.7741 -179.8373 533.4 5 mb 45
2014-04-23T18:21:09.710Z 14.8306 -45.0359 11.74 5.1 mb 54
2014-04-23T08:58:38.730Z -7.475 154.5763 39.91 5 mb 68
2014-04-23T05:40:02.780Z -6.6325 154.5243 43.92 5.4 mb 61
2014-04-21T21:59:05.460Z -6.6023 154.6555 35 5.4 mb 51
2014-04-21T21:41:35.170Z -20.176 -173.8814 33.98 5.3 mb 57
2014-04-21T20:45:23.200Z 17.3559 119.9577 22.5 5.4 mwb 25
2014-04-21T14:57:56.230Z -6.9686 154.7491 46.68 5.3 mb 45
2014-04-21T14:02:15.980Z 51.7675 -175.9442 57.38 5.4 mb 37
2014-04-21T13:39:05.730Z -19.6419 -71.0023 21.1 5.2 mwr 105
2014-04-21T13:37:11.900Z -20.1278 -173.2745 34.03 5.2 mb 83
2014-04-21T12:34:09.990Z 3.9972 91.6065 14.57 5.1 mb 109
2014-04-21T11:25:27.600Z -6.2634 154.4162 35 5.1 mb 50
2014-04-21T09:04:24.330Z -6.1957 154.3797 46.84 5.2 mb 28
2014-04-21T03:21:23.790Z -28.3182 -12.7974 10 5 mb 59
2014-04-20T13:50:41.530Z 53.1022 163.0193 37.31 5.3 mb 41
2014-04-20T13:28:42.990Z -6.8503 154.6607 57.07 5.1 mb 46
2014-04-20T08:43:53.100Z 0.7031 98.3611 48.18 5.4 mb 28
2014-04-20T08:24:29.040Z -6.5001 154.7017 34.87 5 mb 26
2014-04-20T07:45:45.190Z -11.0443 161.6431 18.58 5 mb 43
2014-04-20T04:23:13.160Z -7.0855 154.6438 35.06 5.1 mb 27
2014-04-20T04:17:34.380Z -6.8587 154.5663 28.2 5.7 mwp 49
2014-04-20T01:54:12.710Z -26.5424 -114.9208 10 5.4 mb 91
2014-04-20T00:15:58.660Z -7.1672 155.3119 18.09 6.1 mwp 28
2014-04-20T00:10:44.530Z -7.0093 155.2366 17.31 5.2 mb 31
2014-04-19T23:06:16.900Z -6.9424 154.9865 34.98 5.1 mb 20
2014-04-19T20:54:42.370Z -20.021 -70.913 9.04 5.8 mwr 80
2014-04-19T19:31:34.570Z 17.9617 -62.509 52.07 5 mwr 36
2014-04-19T18:11:24.870Z -7.13 154.664 65.67 5.1 mb 45
catalog_of_earthquakes
Save
Export
style.mss
Map {
background-color: #b8dee6;
}
#countries {
::outline {
line-color: #85c5d3;
line-width: 2;
line-join: round;
}
polygon-fill: #fff;
}
#earthquakes {
marker-width:6;
marker-fill:#4596ff;
marker-line-color:#2a1087;
marker-allow-overlap:true;
}


TileMill
Editor
Projects
Manual
Plugins
Settings
ZOOM 4
catalog_of_earthquakes
Save
Export
style.mss
Map {
background-color: #b8dee6;
}
#countries {
::outline {
line-color: #85c5d3;
line-width: 2;
line-join: round;
}
polygon-fill: #fff;
}
#earthquakes {
marker-width:6;
marker-fill:#4596ff;
marker-line-color:#2a1087;
marker-allow-overlap:true;
}
#earthquakes {
[mag >= 5] {marker-width:6; }
[mag >= 5.5] {marker-width:8; }
[mag >= 6] {marker-width:10; }
[mag >= 7] {marker-width:12; }
[mag >= 8] {marker-width:14; }
}
15:07
14/10/2014


TileMill
Editor
Projects
Manual
Plugins
Settings
Templates
Legend
Teaser
Full
Location
Content to be shown on hover or first tap (mobile).
earthquakes
Layer to use for interaction data
{{{time}}} {{{latitude}}} {{{longitude}}} {{{depth}}} {{{mag}}} {{{magType}}} {{{nst}}} {{{gap}}} {{{dmin}}} {{{rms}}} {{{net}}} {{{id}}} {{{updated}}}
{{{place}}} {{{type}}}
These Mustache tags will be replaced by data. You can also use the full Mustache template language to customize your tooltips.
catalog_of_earthquakes
Save
Export
style.mss
Map {
background-color: #b8dee6;
}
#countries {
::outline {
line-color: #85c5d3;
line-width: 2;
line-join: round;
}
polygon-fill: #fff;
}
#earthquakes {
marker-width:6;
marker-fill:#4596ff;
marker-line-color:#2a1087;
marker-allow-overlap:true;
}
#earthquakes {
[mag >= 5] {marker-width:6; }
[mag >= 5.5] {marker-width:8; }
[mag >= 6] {marker-width:10; }
[mag >= 7] {marker-width:12; }
[mag >= 8] {marker-width:14; }
}
15:13
14/10/2014


TileMill
Templates
Legend
Teaser
Full
Location
Content to be shown on hover or first tap (mobile).
{{{place}}} {{{mag}}} magnitude earthquake
{{{time}}}
earthquakes
Layer to use for interaction data
{{{time}}} {{{latitude}}} {{{longitude}}} {{{depth}}} {{{mag}}} {{{magType}}} {{{nst}}} {{{gap}}} {{{dmin}}} {{{rms}}} {{{net}}} {{{id}}} {{{updated}}} {{{place}}} {{{type}}}
These Mustache tags will be replaced by data. You can also use the full Mustache template language to customize your tooltips.
catalog_of_earthquakes
Save
Export
style.mss
Map {
background-color: #b8dee6;
}
#countries {
::outline {
line-color: #85c5d3;
line-width: 2;
line-join: round;
}
polygon-fill: #fff;
}
#earthquakes {
marker-width:6;
marker-fill:#4596ff;
marker-line-color:#2a1087;
marker-allow-overlap:true;
}
#earthquakes {
[mag >= 5] {marker-width:6; }
[mag >= 5.5] {marker-width:8; }
[mag >= 6] {marker-width:10; }
[mag >= 7] {marker-width:12; }
[mag >= 8] {marker-width:14; }
}


TileMill
Templates
Legend
Teaser
Full
Location
Plain text or HTML map legend.
Magnitude of 5+ earthquakes
circle size indicates magnitude of earthquake
catalog_of_earthquakes
Save
Export
style.mss
Map {
background-color: #b8dee6;
}
#countries {
::outline {
line-color: #85c5d3;
line-width: 2;
line-join: round;
}
polygon-fill: #fff;
}
#earthquakes {
marker-width:6;
marker-fill:#4596ff;
marker-line-color:#2a1087;
marker-allow-overlap:true;
}
#earthquakes {
[mag >= 5] {marker-width:6; }
[mag >= 5.5] {marker-width:8; }
[mag >= 6] {marker-width:10; }
[mag >= 7] {marker-width:12; }
[mag >= 8] {marker-width:14; }
}


TileMill
Editor
Projects
Manual
Plugins
Settings
ZOOM 2
catalog_of_earthquakes
Save
Export
style.mss
Map {
background-color: #b8dee6;
}
#countries {
::outline {
line-color: #85c5d3;
line-width: 2;
line-join: round;
}
polygon-fill: #fff;
}
#earthquakes {
marker-width:6;
marker-fill:#4596ff;
marker-line-color:#2a1087;
marker-allow-overlap:true;
}
#earthquakes {
[mag >= 5] {marker-width:6; }
[mag >= 5.5] {marker-width:8; }
[mag >= 6] {marker-width:10; }
[mag >= 7] {marker-width:12; }
[mag >= 8] {marker-width:14; }
}
Magnitude of 5+ earthquakes
circle size indicates magnitude of earthquake
13:27
16/10/2014

```
# Example 25
# Combine data and spatial locations
# analysis of air quality data from several measurement stations which measure pollution in
# different areas of the urban environment
# source : https://github.com/oscarperpinan/spacetime-vis

setwd("c:/R/Rdata")
library(sp)

## spatial location of stations
airStations <- read.csv("airStations.csv",header=T,sep=";")
str(airStations)
head(airStations)
# the dataframe is converted to a SpatialPointsDataFrame object
coordinates(airStations) <- ~ long + lat
# geographical projection
proj4string(airStations) <- CRS("+proj=longlat +ellps=WGS84 +datum=WGS84")
str(airStations)
```

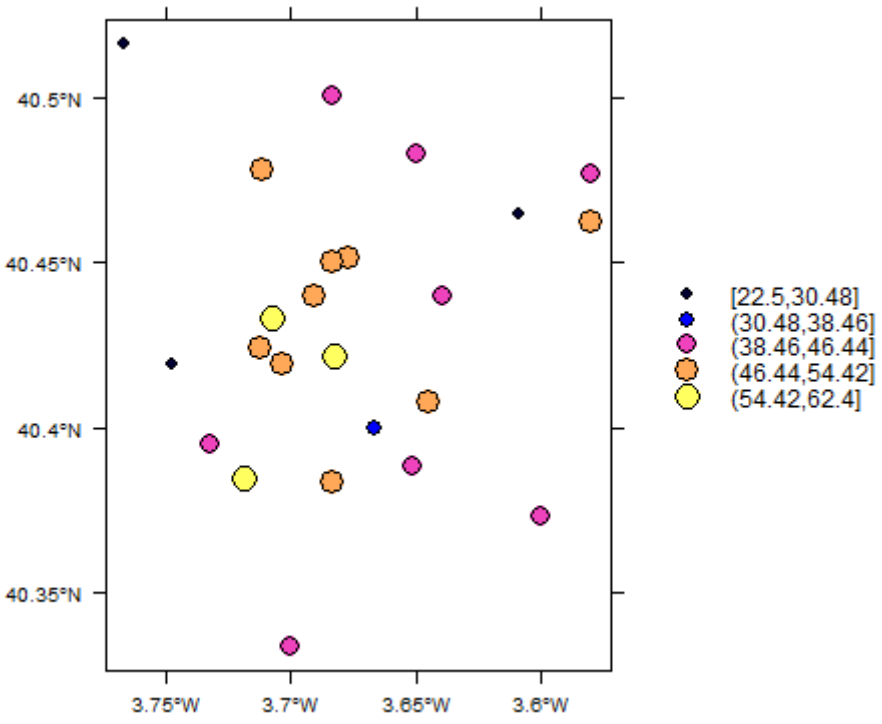
```
> str(airStations)
'data.frame':      24 obs. of  6 variables:
 $ ï..   : int  1 2 3 4 5 6 7 8 9 10 ...
 $ Codigo: int  28079035 28079004 28079039 28079008 28079038 28079011 28079040 28079016
28079017 28079018 ...
 $ Nombre: Factor w/ 24 levels "Arturo Soria",..: 17 16 4 10 7 2 23 1 24 5 ...
 $ long  : num  -3.7 -3.71 -3.71 -3.68 -3.71 ...
 $ lat   : num  40.4 40.4 40.5 40.4 40.4 ...
 $ alt   : int  657 637 673 672 699 708 677 698 NA 581 ...
> head(airStations)
  ï..   Codigo             Nombre      long      lat alt
1   1 28079035    Pza. del Carmen -3.703172 40.41921 657
2   2 28079004    Pza. de EspaÃ±a -3.712333 40.42399 637
3   3 28079039   Barrio del Pilar -3.711542 40.47823 673
4   4 28079008   Escuelas Aguirre -3.682319 40.42156 672
5   5 28079038     Cuatro Caminos -3.707128 40.43333 699
6   6 28079011 Av. RamÃ³n y Cajal -3.677353 40.45147 708
> # the dataframe is converted to a SpatialPointsDataFrame object
> coordinates(airStations) <- ~ long + lat
> # geographical projection
> proj4string(airStations) <- CRS("+proj=longlat +ellps=WGS84 +datum=WGS84")
> str(airStations)
Formal class 'SpatialPointsDataFrame' [package "sp"] with 5 slots
  ..@ data       :'data.frame':       24 obs. of  4 variables:
  .. ..$ ï..   : int [1:24] 1 2 3 4 5 6 7 8 9 10 ...
  .. ..$ Codigo: int [1:24] 28079035 28079004 28079039 28079008 28079038 28079011 28079040
28079016 28079017 28079018 ...
  .. ..$ Nombre: Factor w/ 24 levels "Arturo Soria",..: 17 16 4 10 7 2 23 1 24 5 ...
  .. ..$ alt   : int [1:24] 657 637 673 672 699 708 677 698 NA 581 ...
  ..@ coords.nrs : int [1:2] 4 5
  ..@ coords     : num [1:24, 1:2] -3.7 -3.71 -3.71 -3.68 -3.71 ...
  .. ..- attr(*, "dimnames")=List of 2
  .. .. ..$ : NULL
  .. .. ..$ : chr [1:2] "long" "lat"
  ..@ bbox       : num [1:2, 1:2] -3.77 40.33 -3.58 40.52
  .. ..- attr(*, "dimnames")=List of 2
  .. .. ..$ : chr [1:2] "long" "lat"
  .. .. ..$ : chr [1:2] "min" "max"
  ..@ proj4string:Formal class 'CRS' [package "sp"] with 1 slots
  .. .. ..@ projargs: chr "+proj=longlat +ellps=WGS84 +datum=WGS84"
```

```
# measurements data
airQuality <- read.csv("airQuality.csv",header=T,sep=";")
str(airQuality)

# only interested in NO2
NO2 <- airQuality[airQuality$codParam==8, ]
```

```
head(NO2)
# aggregate data
NO2agg <- aggregate(dat ~ codEst, data=NO2,
                    FUN = function(x) {
                     c(mean=signif(mean(x), 3),
                       median=median(x),
                       sd=signif(sd(x), 3))
                    })
NO2agg
NO2agg <- do.call(cbind, NO2agg)
NO2agg <- as.data.frame(NO2agg)
str(NO2agg)
```

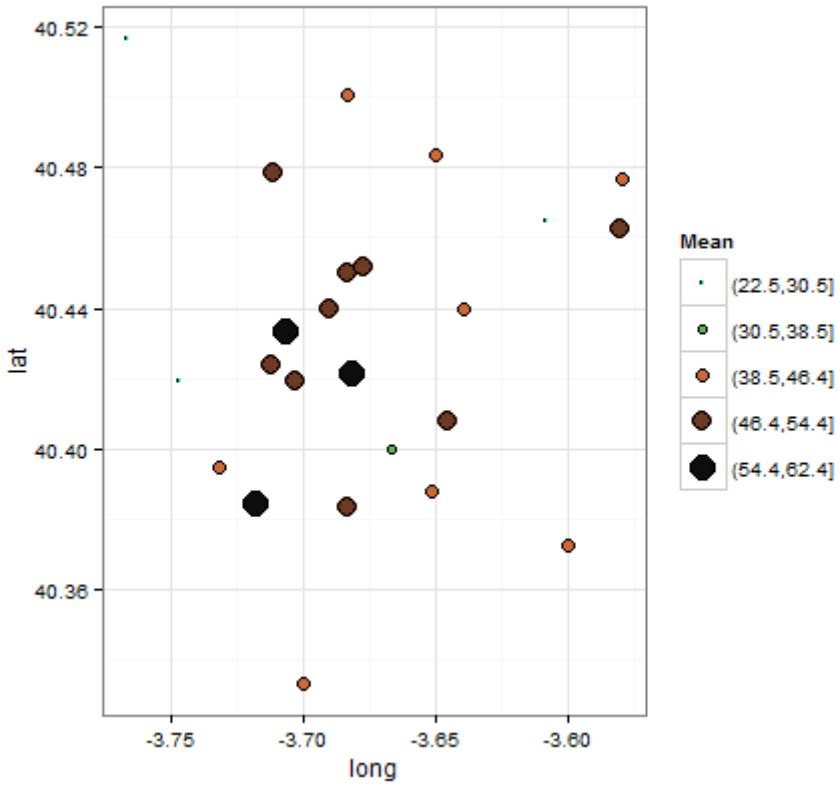
```
> str(airQuality)
'data.frame':       49454 obs. of  7 variables:
 $ X       : int  1 2 3 4 5 6 7 8 9 10 ...
 $ codEst  : int  28079004 28079004 28079004 28079004 28079004 28079004 28079004 28079004
28079004 28079004 ...
 $ codParam: int  1 1 1 1 1 1 1 1 1 ...
 $ month   : int  1 1 1 1 1 1 1 1 1 1 ...
 $ day     : int  1 2 3 4 5 6 7 8 9 10 ...
 $ year    : int  2011 2011 2011 2011 2011 2011 2011 2011 2011 2011 ...
 $ dat     : num  8 9 9 6 7 6 6 5 5 5 ...
>
> # Only interested in NO2
> NO2 <- airQuality[airQuality$codParam==8, ]
> head(NO2)
        X   codEst codParam month day year dat
1090 1090 28079004        8     1   1 2011  36
1091 1091 28079004        8     1   2 2011  52
1092 1092 28079004        8     1   3 2011  54
1093 1093 28079004        8     1   4 2011  38
1094 1094 28079004        8     1   5 2011  47
1095 1095 28079004        8     1   6 2011  34
> # aggregate data
> NO2agg <- aggregate(dat ~ codEst, data=NO2,
+                     FUN = function(x) {
+                       c(mean=signif(mean(x), 3),
+                         median=median(x),
+                         sd=signif(sd(x), 3))
+                     })
> NO2agg
     codEst dat.mean dat.median dat.sd
1  28079004     50.6       49.0   18.3
2  28079008     59.6       58.0   17.7
3  28079011     53.6       51.0   21.8
4  28079016     44.1       41.0   19.2
5  28079017     45.8       38.0   24.9
6  28079018     40.0       37.0   19.8
7  28079024     29.4       26.0   17.2
8  28079027     40.0       37.0   18.3
9  28079035     51.0       46.0   18.6
10 28079036     47.8       45.0   17.9
11 28079038     54.6       51.0   22.7
12 28079039     49.3       43.0   24.2
13 28079040     44.2       41.0   20.0
14 28079047     47.6       44.0   20.9
15 28079048     46.6       45.0   18.1
16 28079049     36.6       34.0   14.8
17 28079050     51.3       49.0   20.1
18 28079054     39.4       36.0   20.4
19 28079055     48.6       47.0   18.8
20 28079056     62.4       59.0   24.4
21 28079057     39.7       35.0   21.0
22 28079058     22.5       20.0   12.4
23 28079059     28.0       27.0   13.8
24 28079060     38.8       35.0   20.0
> NO2agg <- do.call(cbind, NO2agg)
> NO2agg <- as.data.frame(NO2agg)
> str(NO2agg)
'data.frame':       24 obs. of  4 variables:
 $ codEst: num  28079004 28079008 28079011 28079016 28079017 ...
 $ mean  : num  50.6 59.6 53.6 44.1 45.8 40 29.4 40 51 47.8 ...
 $ median: num  49 58 51 41 38 37 26 37 46 45 ...
 $ sd    : num  18.3 17.7 21.8 19.2 24.9 19.8 17.2 18.3 18.6 17.9 ...
```

```
library(maptools)
library(RColorBrewer)
# link aggregated data with stations to obtain a SpatialPointsDataFrame.
# Codigo and codEst are the stations codes
idxNO2 <- match(airStations$Codigo, NO2agg$codEst)
idxNO2
# the aggregated data (a data frame) and the spatial information (a SpatialPointsDataFrame)
# are combined with the spCbind method from the maptools package
NO2sp <- spCbind(airStations[, c('Nombre', 'alt')], NO2agg[idxNO2, ])
str(NO2sp)
save(NO2sp, file="NO2sp.RData")

load("NO2sp.RData")
# proportional symbol mapping

spplot(NO2sp,c("mean"),col.regions=bpy.colors(10),edge.col="black",scales=list(draw=TRUE),
      key.space="right",cex=sqrt(1:5))
```



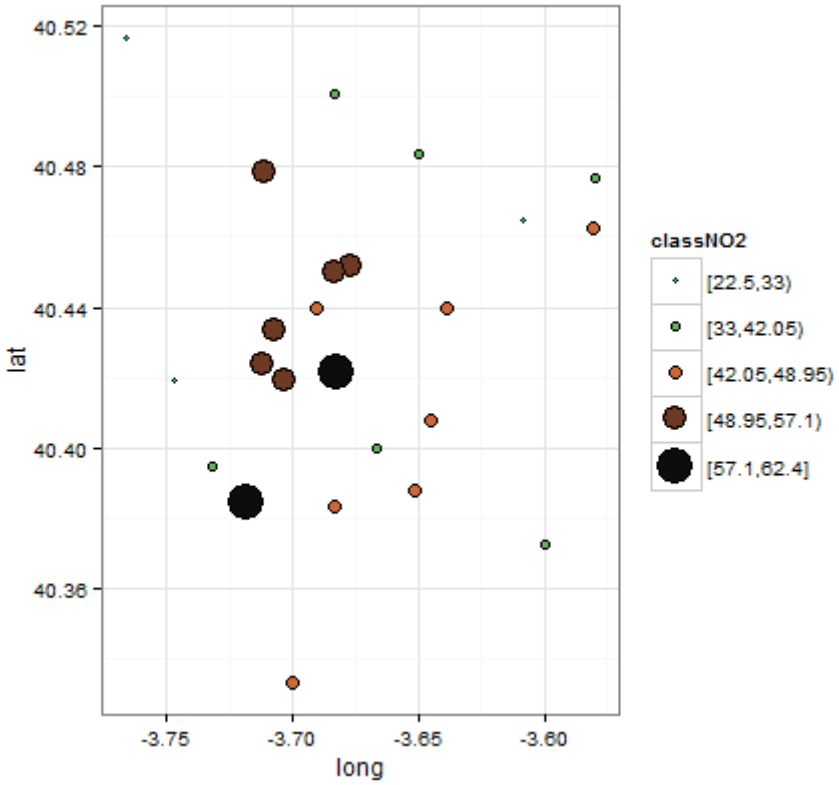

```
# to plot the data with ggplot2 we need to transform the SpatialPointsDataFrame
# into a conventional data frame (which will contain two columns with
# latitude and longitude values)

airPal <- colorRampPalette(c("springgreen1","sienna3","gray5"))(5)

NO2df <- data.frame(NO2sp)
str(NO2df)
NO2df$Mean <- cut(NO2df$mean,5)
```

```
library(ggplot2)
p <- ggplot(data=NO2df,aes(x=long,y=lat,size=Mean,fill=Mean)) +
        geom_point(pch=21,col="black") +
        theme_bw() +
        scale_fill_manual(values=airPal)
p
```

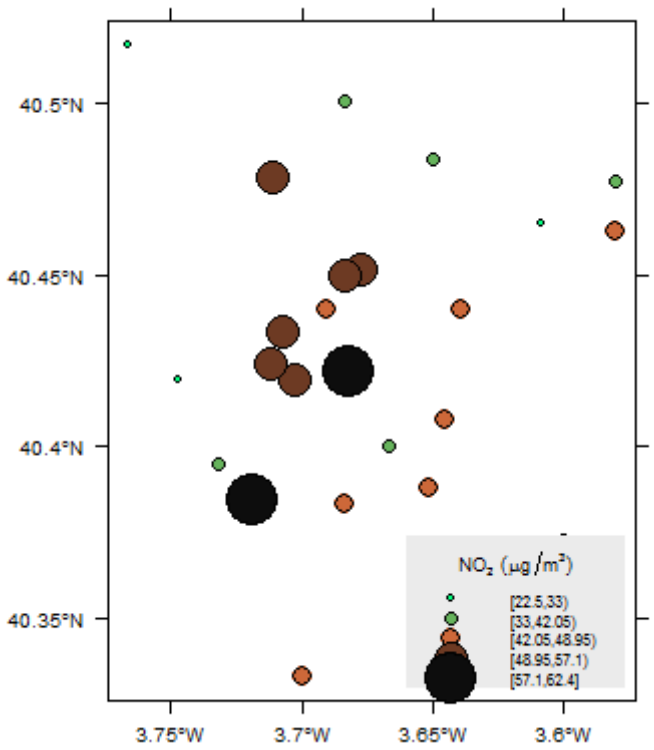



```
# two main improvements can be added :
# define classes dependent on the data structure (instead of a uniform distribution assumed with
  cut)
# encode each group with a symbol size (circle area) such that visual discrimination is enhanced

library(classInt)
nClasses <- 5
intervals <- classIntervals(NO2sp@data$mean,n=nClasses,style="fisher")
tab <- print(intervals)
dent <- c(0.64,1.14,1.65,2.79,4.32,6.22,9.65,12.95,15.11)
dentAQ <- dent[seq_len(nClasses)]
idx <- findCols(intervals)
cexNO2 <- dentAQ[idx]
NO2sp$classNO2 <- factor(names(tab)[idx])
```

```
# ggplot2 version :

NO2df <- data.frame(NO2sp)

ggplot(data=NO2df,aes(x=long,y=lat,size=classNO2,fill=classNO2)) +
    geom_point(pch=21,col="black") +
    theme_bw() +
    scale_fill_manual(values=airPal) +
    scale_size_manual(values=dentAQ*2)
```




```
# spplot version :

spplot(NO2sp["classNO2"],col.regions=airPal,cex=dentAQ,edge.col="black",scales=list(draw=TRUE))

# improved legend :
NO2key <- list(x=0.98, y=0.02,corner=c(1,0),title=expression(NO[2]~~(paste(mu,plain(g))/m^3)),
        cex.title=.75,cex=0.7,background="gray92")

pNO2 <-
spplot(NO2sp["classNO2"],col.regions=airPal,cex=dentAQ,edge.col="black",scales=list(draw=TRUE),
        key.space=NO2key)
pNO2
```



the spatial distribution of points is better understood if we add underlying layers with
information about the spatial context
a suitable method is to make use of the ggmap package

```
str(NO2sp)
madridBox <- bbox(NO2sp)
madridBox
```

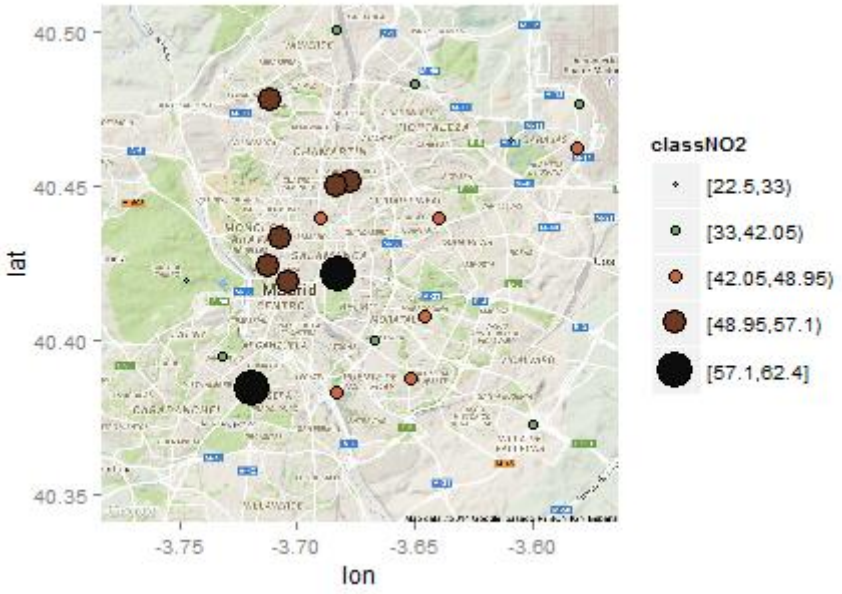
```
> madridBox
           min       max
long -3.766667 -3.580028
lat  40.333333 40.516667
```

```
library(ggmap)
madridGG <- get_map(c(madridBox),source="google")
```

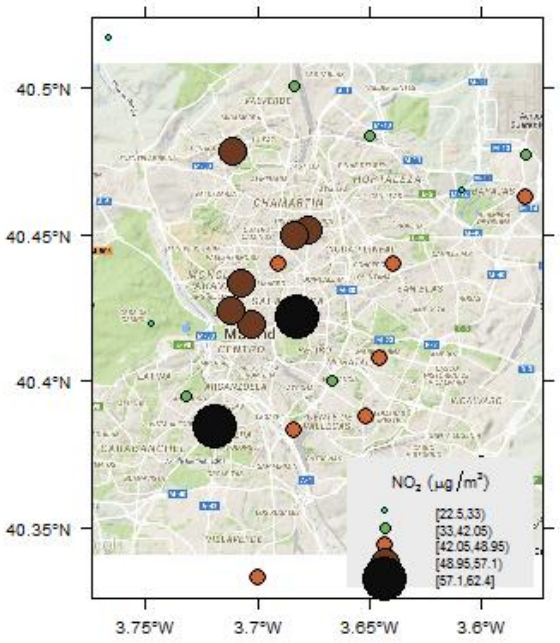
```
> madridGG <- get_map(c(madridBox),source="google")
Warning: bounding box given to google - spatial extent only approximate.
converting bounding box to center/zoom specification. (experimental)
Map from URL : http://maps.googleapis.com/maps/api/staticmap?center=40.425,-
3.673347&zoom=12&size=%20640x640&scale=%202&maptype=terrain&sensor=false
Google Maps API Terms of Service : http://developers.google.com/maps/terms
```

```
madridMap <- ggmap(madridGG)
madridMap
```

```
madridMap +
 geom_point(data=NO2df,aes(x=long,y=lat,size=classNO2,fill=classNO2),pch=21,col="black") +
 scale_fill_manual(values=airPal) +
 scale_size_manual(values=dentAQ*2)
```




```
# the result of ggmap is a raster object with attributes
# it can be displayed with grid.raster as an underlying layer of the previous spplot result

library(grid)
library(latticeExtra)
bbMap <- attr(madridGG,"bb")
height <- with(bbMap,ur.lat - ll.lat)
width <- with(bbMap,ur.lon - ll.lon)
pNO2 + layer(grid.raster(madridGG,width=width,height=height,default.units="native"),under=TRUE)
```



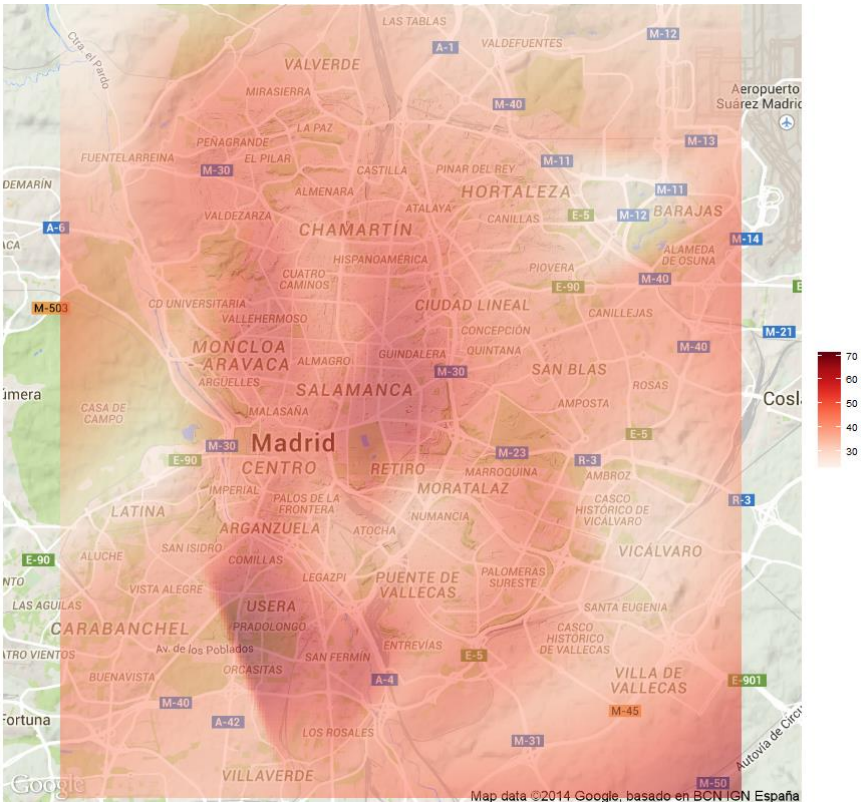
```
# spatial interpolation
# the measurement at discrete points give limited information about the underlying process
# it is quite common to approximate the spatial distribution of the measured variable with
# the interpolation between measurement locations

str(NO2df)
```

```
> str(NO2df)
'data.frame':      24 obs. of  9 variables:
 $ Nombre  : Factor w/ 24 levels "Arturo Soria",..: 17 16 4 10 7 2 23 1 24 5 ...
 $ alt     : int  657 637 673 672 699 708 677 698 NA 581 ...
 $ codEst  : num  28079035 28079004 28079039 28079008 28079038 ...
 $ mean    : num  51 50.6 49.3 59.6 54.6 53.6 44.2 44.1 45.8 40 ...
 $ median  : num  46 49 43 58 51 51 41 41 38 37 ...
 $ sd      : num  18.6 18.3 24.2 17.7 22.7 21.8 20 19.2 24.9 19.8 ...
 $ classNO2: Factor w/ 5 levels "[22.5,33)","[33,42.05)",..: 4 4 4 5 4 4 3 3 3 2 ...
 $ long    : num  -3.7 -3.71 -3.71 -3.68 -3.71 ...
 $ lat     : num  40.4 40.4 40.5 40.4 40.4 ...
```

```
d <- NO2df

# use of interp() function of akima package
library(akima)
akima_li <- interp(x=d$long,
                   y=d$lat,
                   z=d$mean,
                   yo=seq(min(d$lat), max(d$lat), length=250),
                   xo=seq(min(d$long), max(d$long), length=250),
                   linear=FALSE,
                   extrap=TRUE)

dInterp <- data.frame(expand.grid(x=akima_li$x, y=akima_li$y), z=c(akima_li$z))
str(dInterp)
```

```
> str(dInterp)
'data.frame':      62500 obs. of  3 variables:
 $ x: num  -3.77 -3.77 -3.77 -3.76 -3.76 ...
 $ y: num  40.3 40.3 40.3 40.3 40.3 ...
 $ z: num  39.1 39 38.9 38.8 38.7 ...
```

```
plot <- ggmap(madridGG) + geom_tile(data=dInterp, aes(x, y, fill=z), alpha=0.5, color=NA) +
  scale_fill_gradientn(colours=brewer.pal(9,"Reds")) +
  labs(fill="") +
  theme_nothing(legend=TRUE)
plot
```

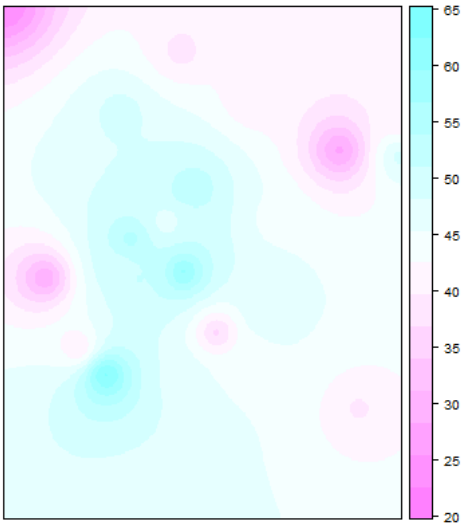



```
# using inverse distance weighted interpolation (IDW) with the gstat package
library(gstat)
class(NO2sp)
proj4string(NO2sp)
```

```
> class(NO2sp)
[1] "SpatialPointsDataFrame"
attr(,"package")
[1] "sp"
> proj4string(NO2sp)
[1] "+proj=longlat +ellps=WGS84 +datum=WGS84"
```

```
airGrid <- spsample(NO2sp,type="regular",n=1e5)
gridded(airGrid) <- TRUE
airKrige <- krige(mean ~ 1,NO2sp,airGrid)
```

```
> airKrige <- krige(mean ~ 1,NO2sp,airGrid)
[inverse distance weighted interpolation]
```



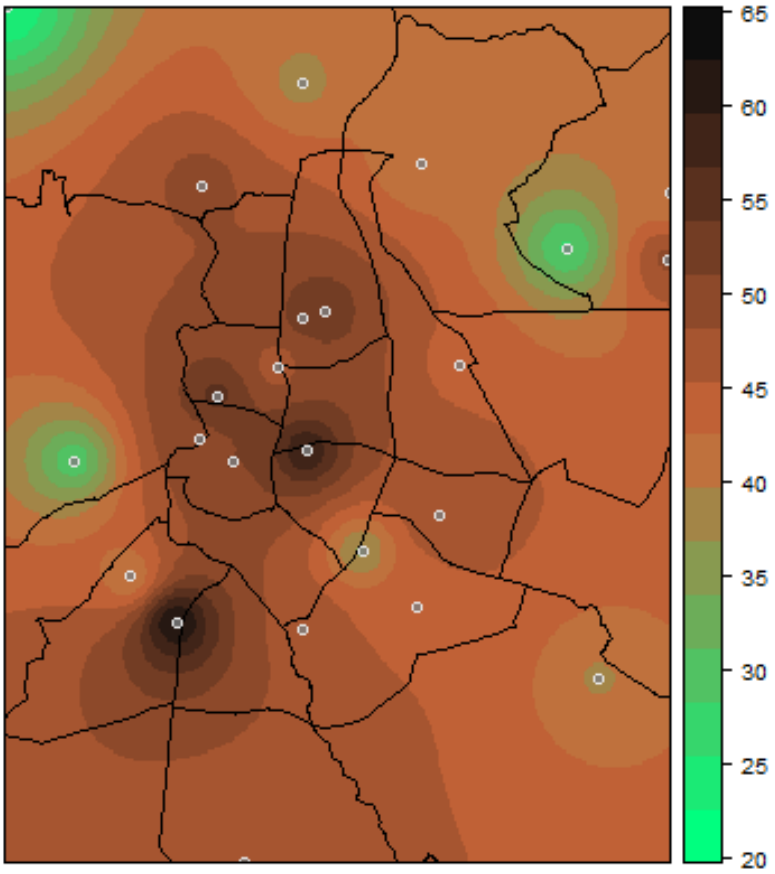

```
# shapefile districts of Madrid
library(rgdal)
madridshapefile <- readOGR(".","Distritos13")
plot(madridshapefile)
```

```
proj4string(madridshapefile)
```

```
> proj4string(madridshapefile)
[1] NA
```

```
proj4string(madridshapefile) <- CRS("+proj=utm +zone30")
distritosMadrid <- spTransform(madridshapefile,CRS=CRS("+proj=longlat +ellps=WGS84"))
```

```
library(grid)
library(latticeExtra)
spplot(airKrige["var1.pred"],col.regions=colorRampPalette(airPal)) +
 layer({
  sp.polygons(distritosMadrid,fill="transparent",lwd=.3)
  sp.points(NO2sp,pch=21,alpha=0.8,fill="gray50",col="white")
 })
```



Example 26
spatiotemporal point observations

Throughout this example we will revisit the data from the preceeding example to illustrate visualization methods applicable for point space-time data. In example 25, the data were converted from spatiotemporal data to spatial data. In this example we will work with the whole space-time dataset using the tools provided by the spacetime package.

As an introduction to this, we will first illustrative how multivariate time series can be used to produce stacked graphs and an innovative visualization also known as streamgraph.

Stacked graphs and the ThemeRiver (also named streamgraph)

```
# stacked graph
# streamgraph

library(lattice)
library(latticeExtra)
library(zoo)
library(colorspace)
library(scales)
library(ggplot2)

setwd("c:/R/Rdata")
unemployUSA <- read.csv("unemployUSA.csv",header=TRUE,sep=",")
str(unemployUSA)
```

```
> str(unemployUSA)
'data.frame':       14 obs. of  170 variables:
 $ Series.ID  : Factor w/ 14 levels "LNU03028615",..: 2 3 4 5 6 7 8 9 10 11 ...
 $ Jan.2000   : int  19 745 734 1000 236 125 228 655 353 782 ...
 $ Feb.2000   : int  25 812 694 1023 223 112 240 587 349 779 ...
 $ Mar.2000   : int  17 669 739 983 192 140 226 623 381 789 ...
 $ Apr.2000   : int  20 447 736 793 191 95 197 517 329 658 ...
 $ May.2000   : int  27 397 685 821 190 131 195 561 423 675 ...
 $ Jun.2000   : int  13 389 621 837 183 102 216 545 452 833 ...
 $ Jul.2000   : int  16 384 708 792 228 144 190 636 478 786 ...
 $ Aug.2000   : int  23 446 685 853 198 143 213 584 450 675 ...
 $ Sep.2000   : int  25 386 667 791 231 130 187 559 398 636 ...
 $ Oct.2000   : int  39 417 693 739 153 96 224 504 339 691 ...
 $ Nov.2000   : int  11 482 672 701 129 117 184 547 351 694 ...
```

```
nms <- unemployUSA$Series.ID
nms
```

```
> nms
 [1] LNU03032230 LNU03032231 LNU03032232 LNU03032235 LNU03032236 LNU03032237 LNU03032238
LNU03032239 LNU03032240 LNU03032241 LNU03032242 LNU03035109
[13] LNU03028615 LNU03035181
14 Levels: LNU03028615 LNU03032230 LNU03032231 LNU03032232 LNU03032235 LNU03032236 LNU03032237
LNU03032238 LNU03032239 LNU03032240 ... LNU03035181
```

```
annualCols <- 14+13*(0:12)
annualCols
```

```
> annualCols
 [1]  14  27  40  53  66  79  92 105 118 131 144 157 170
```

```
# transpose the data and remove colms with annual summaries
unemployUSA <- as.data.frame(t(unemployUSA[,-c(1,annualCols)]))
str(unemployUSA)
head(unemployUSA)
names(unemployUSA) <- substring(nms,7)
head(unemployUSA)
```

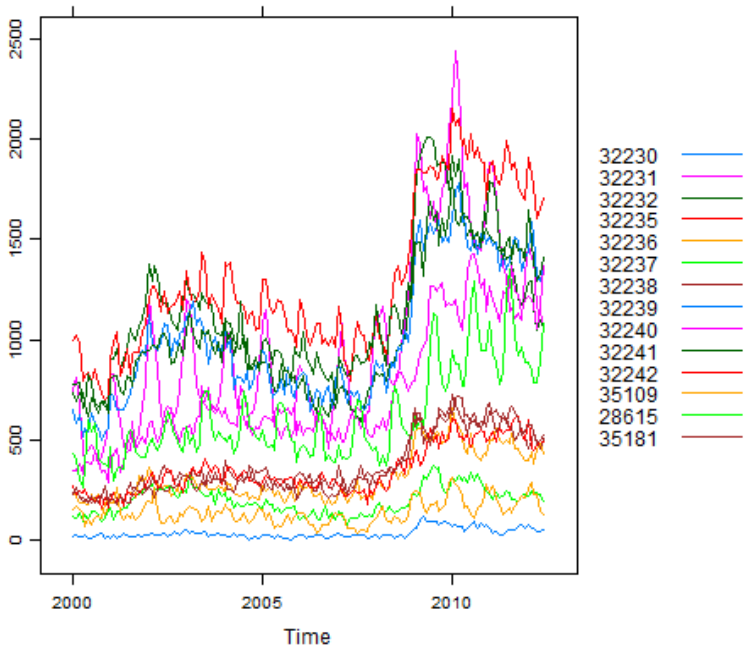
```
> str(unemployUSA)
'data.frame':	156 obs. of  14 variables:
 $ V1 : int  19 25 17 20 27 13 16 23 25 39 ...
 $ V2 : int  745 812 669 447 397 389 384 446 386 417 ...
 $ V3 : int  734 694 739 736 685 621 708 685 667 693 ...
 $ V4 : int  1000 1023 983 793 821 837 792 853 791 739 ...
 $ V5 : int  236 223 192 191 190 183 228 198 231 153 ...
 $ V6 : int  125 112 140 95 131 102 144 143 130 96 ...
 $ V7 : int  228 240 226 197 195 216 190 213 187 224 ...
 $ V8 : int  655 587 623 517 561 545 636 584 559 504 ...
 $ V9 : int  353 349 381 329 423 452 478 450 398 339 ...
 $ V10: int  782 779 789 658 675 833 786 675 636 691 ...
 $ V11: int  274 232 247 240 254 225 202 187 220 161 ...
 $ V12: int  154 173 152 135 73 109 77 110 124 113 ...
 $ V13: int  430 409 311 269 370 603 545 583 408 391 ...
 $ V14: int  239 262 213 218 206 188 222 186 213 226 ...
> head(unemployUSA)
          V1  V2  V3   V4  V5  V6  V7  V8  V9 V10 V11 V12 V13 V14
Jan.2000  19 745 734 1000 236 125 228 655 353 782 274 154 430 239
Feb.2000  25 812 694 1023 223 112 240 587 349 779 232 173 409 262
Mar.2000  17 669 739  983 192 140 226 623 381 789 247 152 311 213
Apr.2000  20 447 736  793 191  95 197 517 329 658 240 135 269 218
May.2000  27 397 685  821 190 131 195 561 423 675 254  73 370 206
Jun.2000  13 389 621  837 183 102 216 545 452 833 225 109 603 188
> names(unemployUSA) <- substring(nms,7)
> head(unemployUSA)
          32230 32231 32232 32235 32236 32237 32238 32239 32240 32241 32242 35109 28615 35181
Jan.2000     19   745   734  1000   236   125   228   655   353   782   274   154   430   239
Feb.2000     25   812   694  1023   223   112   240   587   349   779   232   173   409   262
Mar.2000     17   669   739   983   192   140   226   623   381   789   247   152   311   213
Apr.2000     20   447   736   793   191    95   197   517   329   658   240   135   269   218
May.2000     27   397   685   821   190   131   195   561   423   675   254    73   370   206
Jun.2000     13   389   621   837   183   102   216   545   452   833   225   109   603   188
```

```
# the as.yearmon function of the zoo package converts the character vector of names into a
# yearmon vector
Sys.setlocale("LC_TIME",'C')
idx <- as.yearmon(row.names(unemployUSA),format="%b.%Y")
unemployUSA <- zoo(unemployUSA,idx)
class(unemployUSA)
str(unemployUSA)
head(unemployUSA)
```

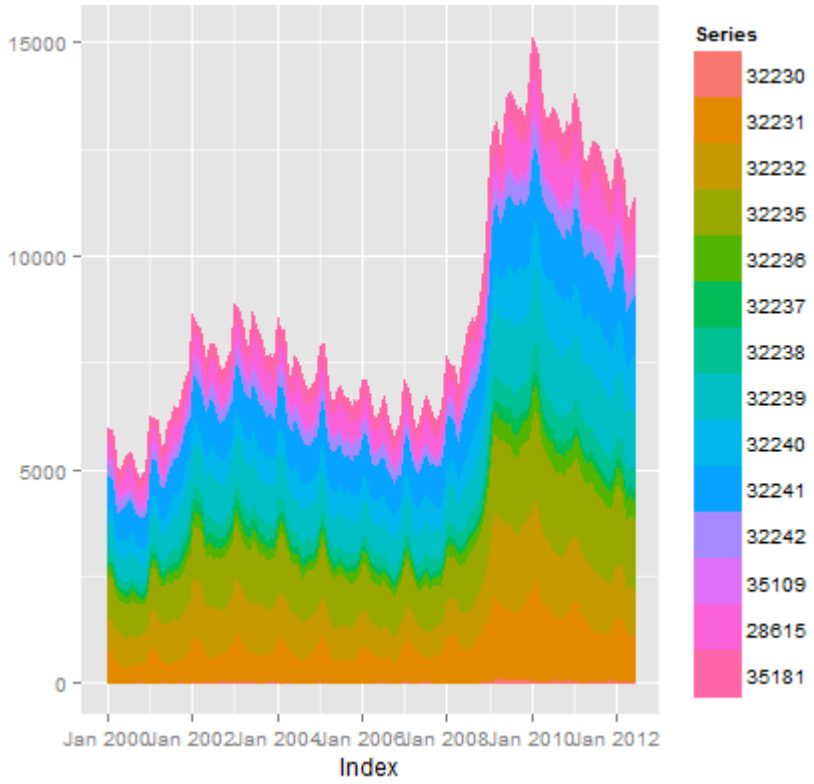
```
> class(unemployUSA)
[1] "zoo"
> str(unemployUSA)
'zoo' series from Jan 2000 to Dec 2012
  Data: int [1:156, 1:14] 19 25 17 20 27 13 16 23 25 39 ...
 - attr(*, "dimnames")=List of 2
  ..$ : chr [1:156] "Jan.2000" "Feb.2000" "Mar.2000" "Apr.2000" ...
  ..$ : chr [1:14] "32230" "32231" "32232" "32235" ...
  Index: Class 'yearmon'  num [1:156] 2000 2000 2000 2000 2000 ...
> head(unemployUSA)
          32230 32231 32232 32235 32236 32237 32238 32239 32240 32241 32242 35109 28615 35181
Jan 2000     19   745   734  1000   236   125   228   655   353   782   274   154   430   239
Feb 2000     25   812   694  1023   223   112   240   587   349   779   232   173   409   262
Mar 2000     17   669   739   983   192   140   226   623   381   789   247   152   311   213
Apr 2000     20   447   736   793   191    95   197   517   329   658   240   135   269   218
May 2000     27   397   685   821   190   131   195   561   423   675   254    73   370   206
Jun 2000     13   389   621   837   183   102   216   545   452   833   225   109   603   188
```

```
# remove rows with NA values
isNA <- apply(is.na(unemployUSA),1,any)
unemployUSA <- unemployUSA[!isNA,]

# the time series of unemployment can be displayed with the xyplot.zoo method
xyplot(unemployUSA)
```


```
xyplot(unemployUSA,superpose=TRUE,auto.key=list(space="right"))
```



autoplot(unemployUSA,facets=NULL,geom="area") + geom_area(aes(fill=Series)) +
scale_x_yearmon()



traditional stacked graphs have their bottom on the x-axis which makes the overall height
easy to estimate
however, with this layout individual layers may be difficult to distinguish
the streamgraph (ThemeRiver) provides an innovative method in which layers are
symmetrical round the x-axis at their center

to create a streamgraph, two functions must work : `panel.flow` and `prepanel.flow`

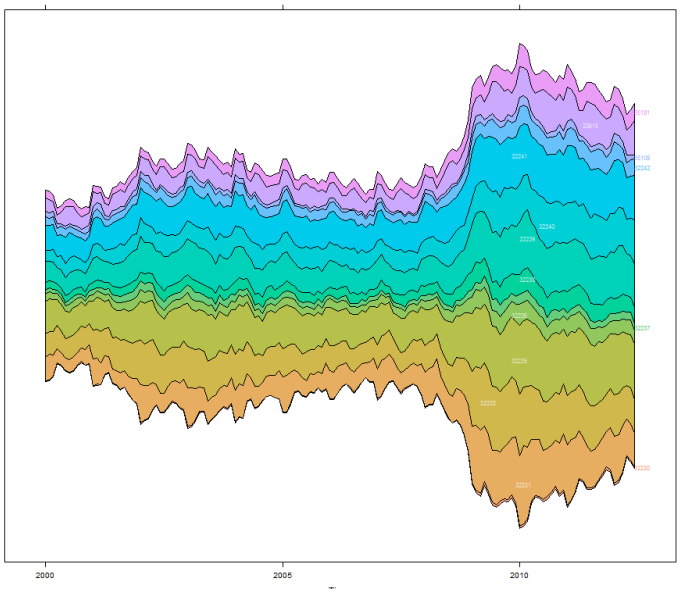
```
panel.flow <- function(x, y, groups, origin, ...){
  dat <- data.frame(x=x, y=y, groups=groups)
  nVars <- nlevels(groups)
  groupLevels <- levels(groups)

  ## From long to wide
  yWide <- unstack(dat, y~groups)
  ## Where are the maxima of each variable located? We will use
  ## them to position labels.
  idxMaxes <- apply(yWide, 2, which.max)

  ##Origin calculated following Havr.eHetzler.ea2002
  if (origin=='themeRiver') origin= -1/2*rowSums(yWide)
  else origin=0
  yWide <- cbind(origin=origin, yWide)
  ## Cumulative sums to define the polygon
```

```
yCumSum <- t(apply(yWide, 1, cumsum))
Y <- as.data.frame(sapply(seq_len(nVars),
                          function(iCol)c(yCumSum[,iCol+1],
                                          rev(yCumSum[,iCol]))))
names(Y) <- levels(groups)
## Back to long format, since xyplot works that way
y <- stack(Y)$values

## Similar but easier for x
xWide <- unstack(dat, x~groups)
x <- rep(c(xWide[,1], rev(xWide[,1])), nVars)
## Groups repeated twice (upper and lower limits of the polygon)
groups <- rep(groups, each=2)

## Graphical parameters
superpose.polygon <- trellis.par.get("superpose.polygon")
col = superpose.polygon$col
border = superpose.polygon$border
lwd = superpose.polygon$lwd

## Draw polygons
for (i in seq_len(nVars)){
  xi <- x[groups==groupLevels[i]]
  yi <- y[groups==groupLevels[i]]
  panel.polygon(xi, yi, border=border,
                lwd=lwd, col=col[i])
}

## Print labels
for (i in seq_len(nVars)){
  xi <- x[groups==groupLevels[i]]
  yi <- y[groups==groupLevels[i]]
  N <- length(xi)/2
  ## Height available for the label
  h <- unit(yi[idxMaxes[i]], 'native') -
    unit(yi[idxMaxes[i] + 2*(N-idxMaxes[i]) +1], 'native')
  ##...converted to "char" units
  hChar <- convertHeight(h, 'char', TRUE)
  ## If there is enough space and we are not at the first or
  ## last variable, then the label is printed inside the polygon.
  if((hChar >= 1) && !(i %in% c(1, nVars))){
    grid.text(groupLevels[i],
              xi[idxMaxes[i]],
              (yi[idxMaxes[i]] +
               yi[idxMaxes[i] + 2*(N-idxMaxes[i]) +1])/2,
              gp = gpar(col='white', alpha=0.7, cex=0.7),
              default.units='native')
  } else {
    ## Elsewhere, the label is printed outside

    grid.text(groupLevels[i],
```

```
                xi[N],
                (yi[N] + yi[N+1])/2,
                gp=gpar(col=col[i], cex=0.7),
                just='left', default.units='native')
    }
  }
}
```

```
prepanel.flow <- function(x, y, groups, origin,...){
  dat <- data.frame(x=x, y=y, groups=groups)
  nVars <- nlevels(groups)
  groupLevels <- levels(groups)
  yWide <- unstack(dat, y~groups)
  if (origin=='themeRiver') origin= -1/2*rowSums(yWide)
  else origin=0
  yWide <- cbind(origin=origin, yWide)
  yCumSum <- t(apply(yWide, 1, cumsum))

  list(xlim=range(x),
       ylim=c(min(yCumSum[,1]), max(yCumSum[,nVars+1])),
       dx=diff(x),
       dy=diff(c(yCumSum[,-1])))
}
```

```
nCols <- ncol(unemployUSA)
nCols
pal <- rainbow_hcl(nCols, c=70, l=75, start=30, end=300)
myTheme <- custom.theme(fill=pal, lwd=0.2)

xyplot(unemployUSA, superpose=TRUE, auto.key=FALSE,
      panel=panel.flow, prepanel=prepanel.flow,
      origin='themeRiver', scales=list(y=list(draw=FALSE)),
      par.settings=myTheme)
```



Another example of plot “stack” and plot “stream”

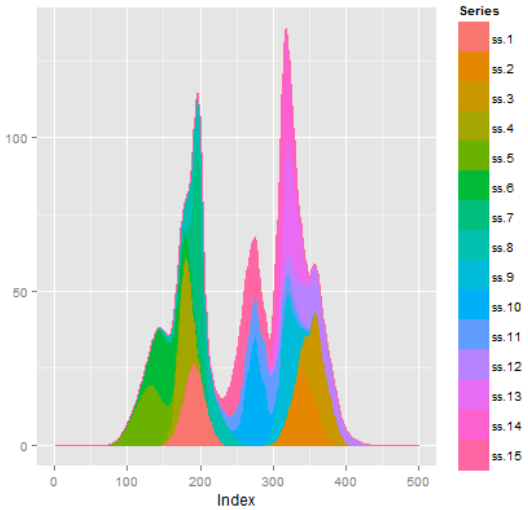
```
# produce some data (“x” is a vector of values (the rows), y is a matrix of data series (the colums)
# corresponding to x
set.seed(1)
m <- 500
n <- 15
x <- seq(m)
y <- matrix(0, nrow=m, ncol=n)
for(i in seq(ncol(y))){
  mu <- runif(1, min=0.25*m, max=0.75*m)
  SD <- runif(1, min=5, max=30)
  TMP <- rnorm(1000, mean=mu, sd=SD)
  HIST <- hist(TMP, breaks=c(0,x), plot=FALSE)
  fit <- smooth.spline(HIST$counts ~ HIST$mids)
  y[,i] <- fit$y
}
class(y)
str(y)
```

```
> class(y)
[1] "matrix"
> str(y)
 num [1:500, 1:15] -1.09e-10 -1.64e-10 -2.19e-10 -2.73e-10 -3.26e-10 ...
```

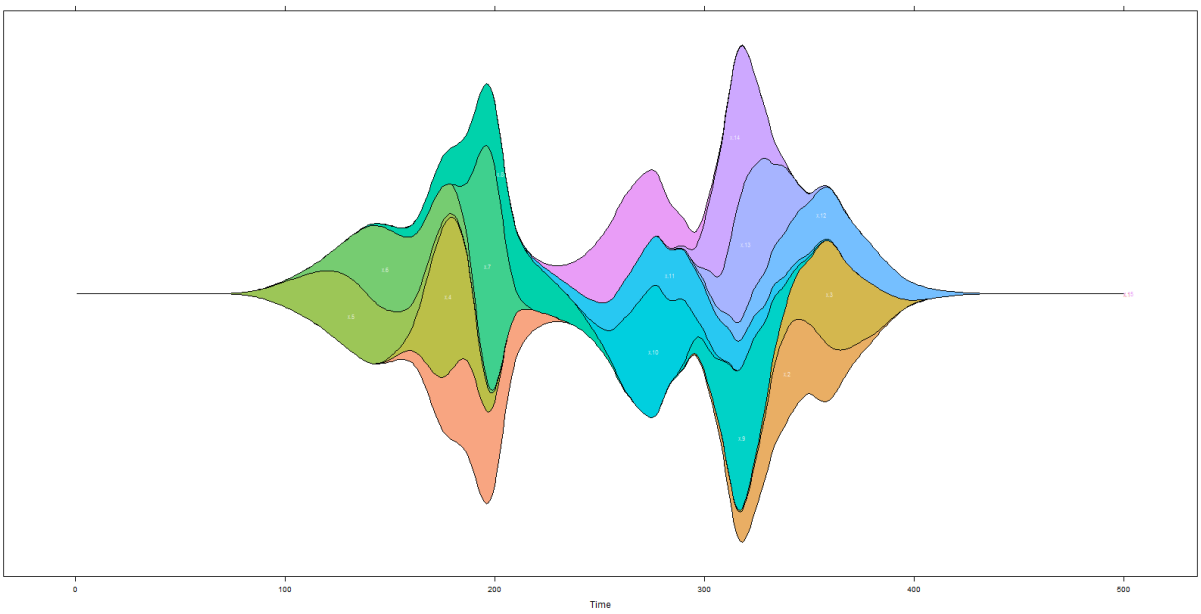
```
library(zoo)
ss <- zoo(y)
class(ss)
str(ss)
```

```
> class(ss)
[1] "zoo"
> str(ss)
‘zoo’ series from 1 to 500
  Data: num [1:500, 1:15] -1.09e-10 -1.64e-10 -2.19e-10 -2.73e-10 -3.26e-10 ...
  Index:  int [1:500] 1 2 3 4 5 6 7 8 9 10 ...
```

```
# stack plot
autoplot(ss,facets=NULL,geom="area") + geom_area(aes(fill=Series))
```



```
# stream plot
nCols <- ncol(ss)
nCols
pal <- rainbow_hcl(nCols, c=70, l=75, start=30, end=300)
myTheme <- custom.theme(fill=pal, lwd=0.2)

xyplot(ss, superpose=TRUE, auto.key=FALSE,
      panel=panel.flow, prepanel=prepanel.flow,
      origin='themeRiver', scales=list(y=list(draw=FALSE)),
      par.settings=myTheme)
```



Spatiotemporal point observations

```
setwd("c:/R/Rdata")
library(sp)

## spatial location of stations
airStations <- read.csv("airStations.csv",header=T,sep=";")
# the dataframe is converted to a SpatialPointsDataFrame object
coordinates(airStations) <- ~ long + lat
# geographical projection
proj4string(airStations) <- CRS("+proj=longlat +ellps=WGS84 +datum=WGS84")
str(airStations)
```

```
> str(airStations)
Formal class 'SpatialPointsDataFrame' [package "sp"] with 5 slots
  ..@ data       :'data.frame':       24 obs. of  4 variables:
  .. ..$ ï..    : int [1:24] 1 2 3 4 5 6 7 8 9 10 ...
  .. ..$ Codigo: int [1:24] 28079035 28079004 28079039 28079008 28079038 28079011 28079040
28079016 28079017 28079018 ...
  .. ..$ Nombre: Factor w/ 24 levels "Arturo Soria",..: 17 16 4 10 7 2 23 1 24 5 ...
  .. ..$ alt    : int [1:24] 657 637 673 672 699 708 677 698 NA 581 ...
  ..@ coords.nrs : int [1:2] 4 5
  ..@ coords     : num [1:24, 1:2] -3.7 -3.71 -3.71 -3.68 -3.71 ...
  .. ..- attr(*, "dimnames")=List of 2
  .. .. ..$ : NULL
  .. .. ..$ : chr [1:2] "long" "lat"
  ..@ bbox       : num [1:2, 1:2] -3.77 40.33 -3.58 40.52
  .. ..- attr(*, "dimnames")=List of 2
  .. .. ..$ : chr [1:2] "long" "lat"
  .. .. ..$ : chr [1:2] "min" "max"
  ..@ proj4string:Formal class 'CRS' [package "sp"] with 1 slots
  .. .. ..@ projargs: chr "+proj=longlat +ellps=WGS84 +datum=WGS84"
```

```
# measurements data
airQuality <- read.csv("airQuality.csv",header=T,sep=";")
str(airQuality)
# only interested in NO2
NO2 <- airQuality[airQuality$codParam==8, ]
head(NO2)
```

```
> head(NO2)
        X   codEst codParam month day year dat
1090 1090 28079004        8     1   1 2011  36
1091 1091 28079004        8     1   2 2011  52
1092 1092 28079004        8     1   3 2011  54
1093 1093 28079004        8     1   4 2011  38
1094 1094 28079004        8     1   5 2011  47
1095 1095 28079004        8     1   6 2011  34
```

```
library(zoo)
library(spacetime)
# in NO2 each line corresponds with a measurement at one station during a day of the year
# we need a data frame with each station as a different variable during a day of the year
# this means we have to convert the data from long to wide

NO2$time <- with(NO2,ISOdate(year,month,day))
NO2 <- subset(NO2,select=c(codEst,dat,time))
str(NO2)
head(NO2)
```

```
> str(NO2)
'data.frame':       8702 obs. of  3 variables:
 $ codEst: int  28079004 28079004 28079004 28079004 28079004 28079004 28079004 28079004
28079004 28079004 ...
 $ dat   : num  36 52 54 38 47 34 39 42 36 38 ...
 $ time  : POSIXct, format: "2011-01-01 12:00:00" "2011-01-02 12:00:00" "2011-01-03 12:00:00"
"2011-01-04 12:00:00" ...
> head(NO2)
       codEst dat                time
1090 28079004  36 2011-01-01 12:00:00
1091 28079004  52 2011-01-02 12:00:00
1092 28079004  54 2011-01-03 12:00:00
1093 28079004  38 2011-01-04 12:00:00
1094 28079004  47 2011-01-05 12:00:00
1095 28079004  34 2011-01-06 12:00:00
```

```
library(reshape2)
NO2wide <- dcast(NO2,time ~ codEst,value.var="dat")
str(NO2wide)
head(NO2wide)
```

```
> str(NO2wide)
'data.frame':       365 obs. of  25 variables:
 $ time    : POSIXct, format: "2011-01-01 12:00:00" "2011-01-02 12:00:00" "2011-01-03
12:00:00" "2011-01-04 12:00:00" ...
 $ 28079004: num  36 52 54 38 47 34 39 42 36 38 ...
 $ 28079008: num  50 57 68 51 52 37 45 42 49 53 ...
 $ 28079011: num  48 57 76 55 63 49 58 60 59 56 ...
 $ 28079016: num  41 52 72 61 63 41 50 49 47 62 ...
 $ 28079017: num  52 55 82 48 55 38 44 36 39 51 ...
 $ 28079018: num  44 52 51 39 49 34 40 40 37 37 ...
 $ 28079024: num  27 36 40 21 39 29 30 29 22 20 ...
 $ 28079027: num  42 47 72 56 57 33 41 37 48 63 ...
 $ 28079035: num  48 58 63 45 50 38 48 45 45 41 ...
 $ 28079036: num  45 48 68 50 54 33 42 41 44 53 ...
 $ 28079038: num  53 62 76 50 58 44 49 50 53 53 ...
 $ 28079039: num  44 49 70 42 52 40 47 45 42 46 ...
 $ 28079040: num  47 50 70 53 59 34 41 39 48 56 ...
 $ 28079047: num  46 51 62 43 52 36 41 40 41 41 ...
 $ 28079048: num  38 44 62 46 51 42 48 49 48 49 ...
 $ 28079049: num  37 45 56 43 50 33 38 36 37 32 ...
 $ 28079050: num  39 41 61 51 56 38 46 47 51 54 ...
 $ 28079054: num  36 41 64 41 40 16 22 22 37 52 ...
 $ 28079055: num  48 49 71 57 57 34 46 39 52 63 ...
 $ 28079056: num  55 69 70 47 61 47 53 60 57 51 ...
 $ 28079057: num  37 51 76 57 53 38 44 41 44 52 ...
 $ 28079058: num  19 21 28 26 29 21 25 29 18 21 ...
 $ 28079059: num  25 31 47 41 44 25 29 25 26 39 ...
 $ 28079060: num  38 46 72 47 47 35 40 38 39 46 ...
```

```
> head(NO2wide)
                 time 28079004 28079008 28079011 28079016 28079017 28079018 28079024 28079027
28079035 28079036 28079038 28079039 28079040 28079047
1 2011-01-01 12:00:00       36       50       48       41       52       44       27       42
48       45       53       44       47       46
2 2011-01-02 12:00:00       52       57       57       52       55       52       36       47
58       48       62       49       50       51
3 2011-01-03 12:00:00       54       68       76       72       82       51       40       72
63       68       76       70       70       62
4 2011-01-04 12:00:00       38       51       55       61       48       39       21       56
45       50       50       42       53       43
5 2011-01-05 12:00:00       47       52       63       63       55       49       39       57
50       54       58       52       59       52
6 2011-01-06 12:00:00       34       37       49       41       38       34       29       33
38       33       44       40       34       36
  28079048 28079049 28079050 28079054 28079055 28079056 28079057 28079058 28079059 28079060
1       38       37       39       36       48       55       37       19       25       38
2       44       45       41       41       49       69       51       21       31       46
3       62       56       61       64       71       70       76       28       47       72
4       46       43       51       41       57       47       57       26       41       47
5       51       50       56       40       57       61       53       29       44       47
6       42       33       38       16       34       47       38       21       25       35
```

```
NO2zoo <- zoo(NO2wide[,-1],NO2wide$time)
str(NO2zoo)
head(NO2zoo)
class(NO2zoo)
dats <- data.frame(vals=as.vector(t(NO2zoo)))
str(dats)
head(dats)
class(dats)
```

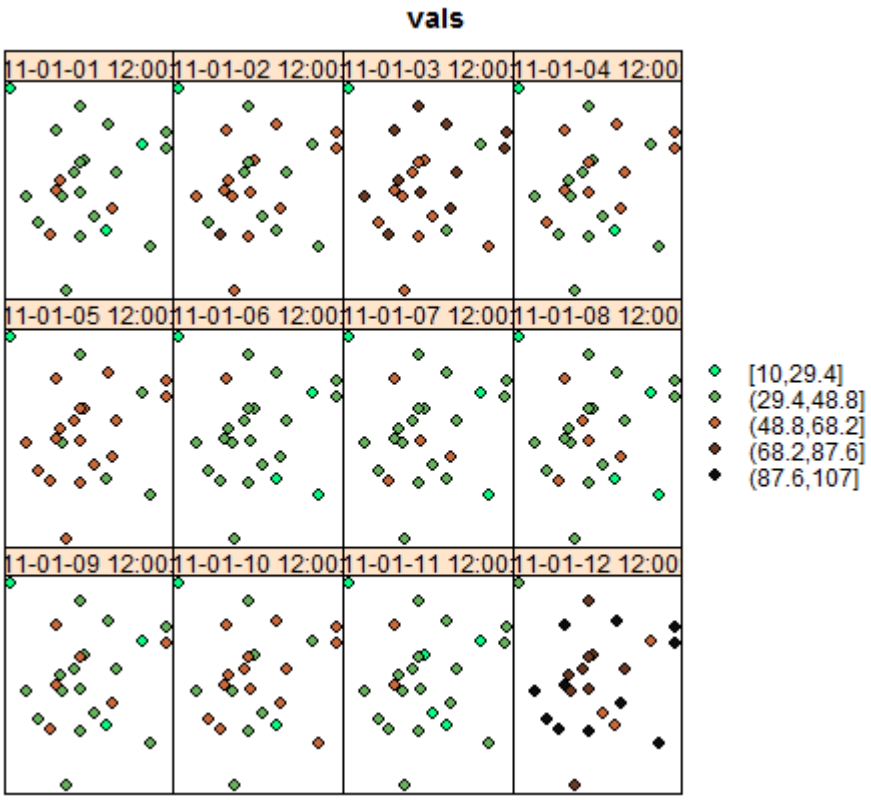
```
> class(NO2zoo)
[1] "zoo"
> dats <- data.frame(vals=as.vector(t(NO2zoo)))
> str(dats)
'data.frame':       8760 obs. of  1 variable:
 $ vals: num  36 50 48 41 52 44 27 42 48 45 ...
> head(dats)
  vals
1   36
2   50
3   48
4   41
5   52
6   44
> class(dats)
[1] "data.frame"
```

```
NO2st <- STFDF(airStations,index(NO2zoo),dats)
str(NO2st)
class(NO2st)
```

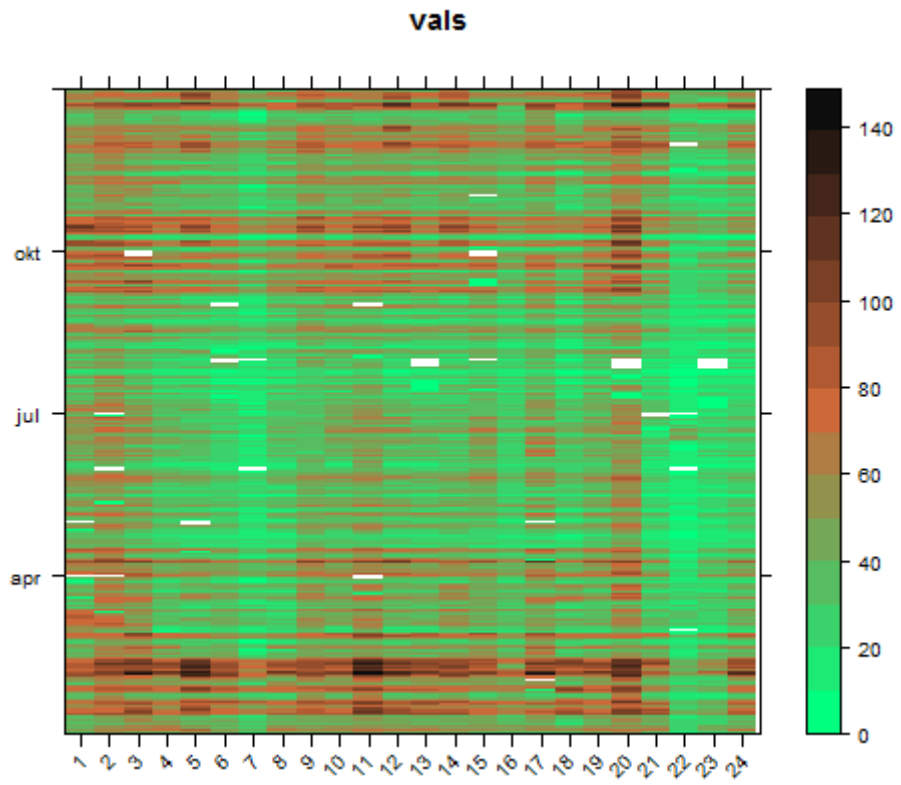
```
> str(NO2st)
Formal class 'STFDF' [package "spacetime"] with 4 slots
  ..@ data   :'data.frame':  8760 obs. of  1 variable:
  .. ..$ vals: num [1:8760] 36 50 48 41 52 44 27 42 48 45 ...
  ..@ sp     :Formal class 'SpatialPointsDataFrame' [package "sp"] with 5 slots
  .. .. ..@ data       :'data.frame': 24 obs. of  4 variables:
  .. .. .. ..$ ï..    : int [1:24] 1 2 3 4 5 6 7 8 9 10 ...
  .. .. .. ..$ Codigo: int [1:24] 28079035 28079004 28079039 28079008 28079038 28079011
28079040 28079016 28079017 28079018 ...
  .. .. .. ..$ Nombre: Factor w/ 24 levels "Arturo Soria",..: 17 16 4 10 7 2 23 1 24 5 ...
  .. .. .. ..$ alt    : int [1:24] 657 637 673 672 699 708 677 698 NA 581 ...
  .. .. ..@ coords.nrs : int [1:2] 4 5
  .. .. ..@ coords     : num [1:24, 1:2] -3.7 -3.71 -3.71 -3.68 -3.71 ...
  .. .. .. ..- attr(*, "dimnames")=List of 2
  .. .. .. .. ..$ : NULL
  .. .. .. .. ..$ : chr [1:2] "long" "lat"
  .. .. ..@ bbox       : num [1:2, 1:2] -3.77 40.33 -3.58 40.52
  .. .. .. ..- attr(*, "dimnames")=List of 2
  .. .. .. .. ..$ : chr [1:2] "long" "lat"
  .. .. .. .. ..$ : chr [1:2] "min" "max"
  .. .. ..@ proj4string:Formal class 'CRS' [package "sp"] with 1 slots
  .. .. .. .. ..@ projargs: chr "+proj=longlat +ellps=WGS84 +datum=WGS84"
  ..@ time   :An ‘xts’ object on 2011-01-01 12:00:00/2011-12-31 12:00:00 containing:
```

```
  Data: int [1:365, 1] 1 2 3 4 5 6 7 8 9 10 ...
 - attr(*, "dimnames")=List of 2
  ..$ : NULL
  ..$ : chr "timeIndex"
  Indexed by objects of class: [POSIXct,POSIXt] TZ: GMT
  xts Attributes:
 NULL
  ..@ endTime: POSIXct[1:365], format: "2011-01-02 12:00:00" "2011-01-03 12:00:00" "2011-01-04
12:00:00" "2011-01-05 12:00:00" ...
> class(NO2st)
[1] "STFDF"
attr(,"package")
[1] "spacetime"
```

airPal <- colorRampPalette(c("springgreen","sienna3","gray5"))(5)
stplot(NO2st[,1:12],cuts=5,col.regions=airPal,edge.col="black")



```
stplot(NO2st,mode="xt",col.regions=colorRampPalette(airPal)(15),
    scales=list(x=list(rot=45)),xlab="",ylab="")
```



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