Cartography *firefly*

Firefly maps are promoted and described by John Nelson who published a post in 2016 about its characteristics. However, these types of maps are linked to ArcGIS, which has led me to try to recreate them in R. The recent `ggplot2` extension `ggshadow` facilitates the creation of this cartographic style. It is characterized by three elements 1) a dark and unsaturated basemap (eg satellite imagery) 2) a masked vignette and highlighted area and 3) a single bright thematic layer. The essential are the colors and the brightness that is achieved with cold colors, usually neon colors. John Nelson explains more details in this post.

What is the *firefly* style for? In the words of John Nelson: “the map style that captures our attention and dutifully honors the First Law of Geography”. John refers to what was said by Waldo Tobler “everything is related to everything else, but near things are more related than distant things” (Tobler 1970).

In this post we will visualize all earthquakes recorded in southwestern Europe with a magnitude greater than 3.

Packages

We will use the following packages:

Package	Description
tidyverse	Collection of packages (visualization, manipulation): ggplot2, dplyr, purrr, etc.
plotwidgets	Contains functions for color conversion (RGB, HSL)
terra	Import, export and manipulate raster (raster successor package)
raster	Import, export and manipulate raster
sf	Simple Feature: import, export and manipulate vector data
ggshadow	ggplot2 extension for shaded and glow geometries
ggspatial	ggplot2 extension for spatial objects
ggnewscale	ggplot2 extension to create multiple scales
janitor	Simple functions to examine and clean data
rnaturalearth	Vector maps of the world ‘Natural Earth’

```
# install the packages if necessary

if(!require("tidyverse")) install.packages("tidyverse")
if(!require("sf")) install.packages("sf")
if(!require("terra")) install.packages("terra")
if(!require("raster")) install.packages("raster")
if(!require("plotwidgets")) install.packages("plotwidgets")
if(!require("ggshadow")) install.packages("ggshadow")
if(!require("ggspatial")) install.packages("ggspatial")
if(!require("ggnewscale")) install.packages("ggnewscale")
if(!require("janitor")) install.packages("janitor")
if(!require("rnaturalearth")) install.packages("rnaturalearth")

# load packages
```

```
library(raster)
library(terra)
library(sf)
library(tidyverse)
library(plotwidgets)
library(ggshadow)
library(ggspatial)
library(ggnewscale)
library(janitor)
library(rnaturalearth)
```

Preparation

Data

First we download all the necessary data. For the base map we will use the Blue Marble imagery via the access to worldview.earthdata.nasa.gov where I have downloaded a selection of the area of interest in geoTiff format with a resolution of 1 km. It is important to adjust the resolution to the necessary detail of the map.

- Blue Marble selection via worldview.earthdata.nasa.gov (~ 66 MB) download
- Records of historical earthquakes in southwestern Europe from IGN download

Import

The first thing we do is to import the RGB *Blue Marble* raster and the earthquake data. To import the raster I use the new package `terra` which is the successor of the `raster` package. You can find a recent comparison here. Not all packages are yet compatible with the new `SpatRaster` class, so we also need the `raster` package.

```
# earthquakes

earthquakes <- read.csv2("catalogoComunSV_1621713848556.csv")
str(earthquakes)
## 'data.frame':    149724 obs. of  10 variables:
##  $ Evento       : chr  "          33" "          34" "          35"
"          36" ...
##  $ Fecha        : chr  "  02/03/1373" "  03/03/1373" "  08/03/1373"
"  19/03/1373" ...
##  $ Hora         : chr  "    00:00:00" "    00:00:00" "    00:00:00"
"    00:00:00" ...
##  $ Latitud      : chr  "     42.5000" "     42.5000" "     42.5000"
"     42.5000" ...
##  $ Longitud     : chr  "      0.7500" "      0.7500" "      0.7500"
"      0.7500" ...
##  $ Prof...Km.   : int  NA NA NA NA NA NA NA NA NA NA ...
##  $ Inten.       : chr  "     VIII-IX" "            " "            "
"            " ...
##  $ Mag.         : chr  "            " "            " "            "
"            " ...
##  $ Tipo.Mag.    : int  NA NA NA NA NA NA NA NA NA NA ...
##  $ LocalizaciÃ³n: chr  "RibagorÃ§a.L" "RibagorÃ§a.L" "RibagorÃ§a.L"
"RibagorÃ§a.L" ...
```

```
# Blue Marble RGB raster

bm <- rast("snapshot-2017-11-30T00_00_00Z.tiff")
bm # contains three layers (red, green, blue)
## class       : SpatRaster
## dimensions  : 7156, 7156, 3  (nrow, ncol, nlyr)
## resolution  : 0.008789272, 0.008789272  (x, y)
## extent      : -33.49823, 29.39781, 15.77547, 78.67151  (xmin, xmax,
ymin, ymax)
## coord. ref. : +proj=longlat +datum=WGS84 +no_defs
## source      : snapshot-2017-11-30T00_00_00Z.tiff
## red-grn-blue: 1, 2, 3
## names       : sna_1, sna_2, sna_3
# plot

plotRGB(bm)
```

```
# country boundaries

limits <- ne_countries(scale = 50, returnclass = "sf")
```

Earthquakes

In this step we clean the imported earthquakes data. 1) We convert longitude, latitude and magnitude into numeric using the `parse_number()` function and clean the column names with the `clean_names()` function, 2) We create a spatial object `sf` and project it using the EPSG:3035 corresponding to ETRS89-extended/LAEA Europe.

```
# we clean the data and create an sf object

earthquakes <-  earthquakes %>% clean_names() %>%
                  mutate(across(c(mag, latitud, longitud),
parse_number)) %>%
                 st_as_sf(coords = c("longitud", "latitud"),
                       crs = 4326) %>%
```

```
st_transform(3035) # project to Laea
```

Blue Marble background Map

We cropped the background map to a smaller extent, but we still haven't limited to the final area yet.

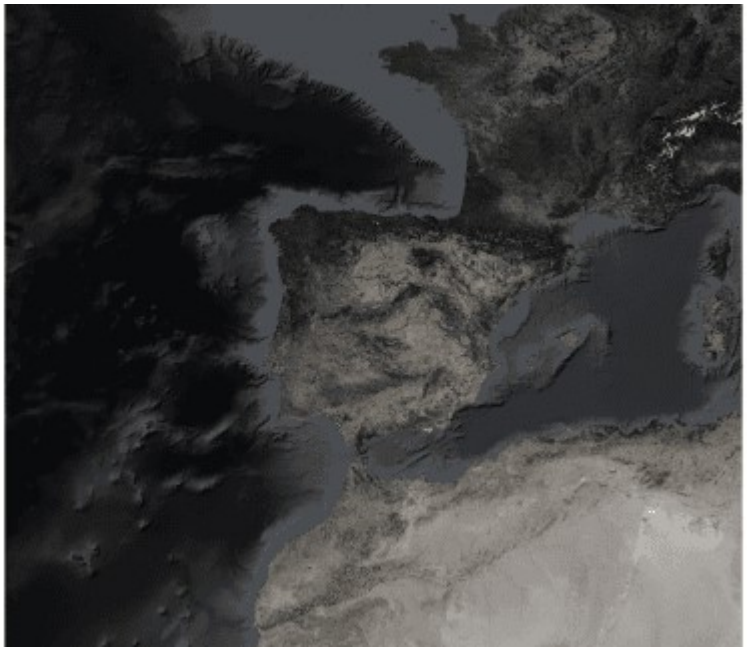
```
# clip to the desired area

bm <- crop(bm, extent(-20, 10, 30, 50)) # W, E, S, N
```

To obtain an unsaturated version of the Blue Marble RGB raster, we must apply a function created for this purpose. In this, we use the `rgb2hsl()` function from the `plotwidgets` package, which helps us converting RGB to HSL and vice versa. The HSL model is defined by Hue, Saturation, Lightness. The last two parameters are expressed in ratio or percentage. The hue is defined on a color wheel from 0 to 360º. 0 is red, 120 is green, 240 is blue. To change the saturation we only have to reduce the value of S.

```
# function to change saturation from RGB

saturation <- function(rgb, s = .5){

  hsl <- rgb2hsl(as.matrix(rgb))
  hsl[2, ] <- s

  rgb_new <- as.vector(t(hsl2rgb(hsl)))

  return(rgb_new)

}
```

We employ our `saturation()` function using the `app()` function that applies it to each pixel with the three RGB layers. We add the argument `s`, which defines the desired saturation level. This step may take several minutes. Then we project our RGB image.

```
# apply the function to unsaturate with 5%

bm_desat <- app(bm, saturation, s = .05)

# plot new RGB image

plotRGB(bm_desat)
```



```
# project

bm_desat <- terra::project(bm_desat, "epsg:3035")
```

Firefly map construction

Boundaries and graticules

Before starting to build the map, we create graticules and set the final map limits.

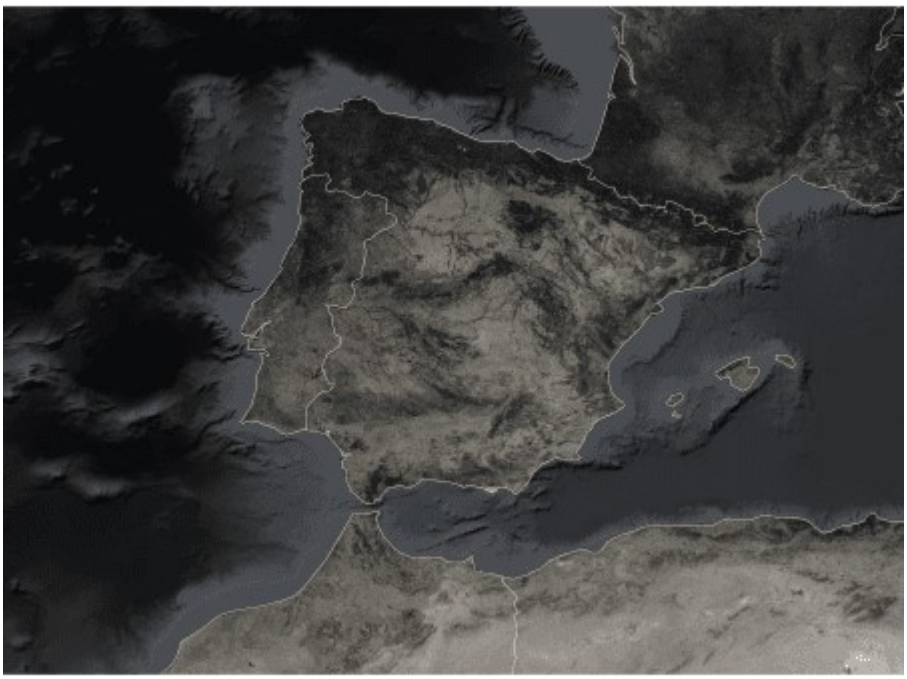
```
# define the final map extent

bx <- tibble(x = c(-13, 6.7), y = c(31, 47)) %>%
       st_as_sf(coords = c("x", "y"), crs = 4326) %>%
        st_transform(3035) %>%
         st_bbox()

# create map graticules

grid <- st_graticule(earthquakes)
```

Map with image background

The `layer_spatial()` function of `ggspatial` allows us to add an RGB raster without major problems, however, it still does not support the new`SpatRaster` class. Therefore, we must convert it to the `stack` class with the `stack()` function. It is also possible to use instead of `geom_sf()`, the `layer_spatial()` function for vector objects of class `sf` or`sp`.

```
ggplot() +
  layer_spatial(data = stack(bm_desat)) + # blue marble background map
  geom_sf(data = limits, fill = NA, size = .3, colour = "white") + #
country boundaries
  coord_sf(xlim = bx[c(1, 3)],
           ylim = bx[c(2, 4)],
           crs = 3035,
```

```
          expand = FALSE) +
  theme_void()
```



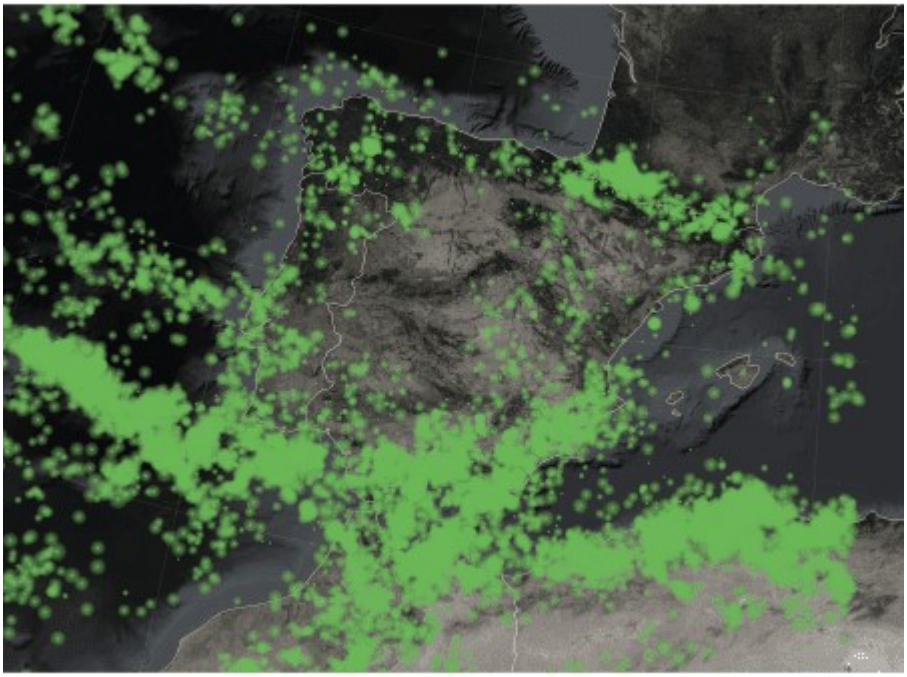
Map with background and earthquakes

To create the glow effect on *firefly* maps, we use the `geom_glowpoint()` function from the `ggshadow` package. There is also the same function for lines. Since our data is of spatial class `sf` and the geometry `sf` is not directly supported, we must indicate as an argument `stats = "sf_coordinates"` and inside `aes()` indicate `geometry = geometry`. We will map the size of the points as a function of magnitude. In addition, we filter those earthquakes with a magnitude greater than 3.

Inside the `geom_glowpoint()` function, 1) we define the desired color for the point and the glow effect, 2) the degree of transparency with `alpha` either for the point or for the glow. Finally, in the `scale_size()` function we set the range (minimum, maximum) of the size that the points will have.

```
ggplot() +
  layer_spatial(data = stack(bm_desat)) +
  geom_sf(data = limits, fill = NA, size = .3, colour = "white") +
  geom_sf(data = grid, colour = "white", size = .1, alpha = .5) +
  geom_glowpoint(data = filter(earthquakes, mag > 3),
                 aes(geometry = geometry, size = mag),
                   alpha = .8,
                   color = "#6bb857",
                   shadowcolour = "#6bb857",
                   shadowalpha = .1,
                   stat = "sf_coordinates",
```

```
                  show.legend = FALSE) +
  scale_size(range = c(.1, 1.5)) +
  coord_sf(xlim = bx[c(1, 3)],
           ylim = bx[c(2, 4)],
           crs = 3035,
           expand = FALSE) +
  theme_void()
```



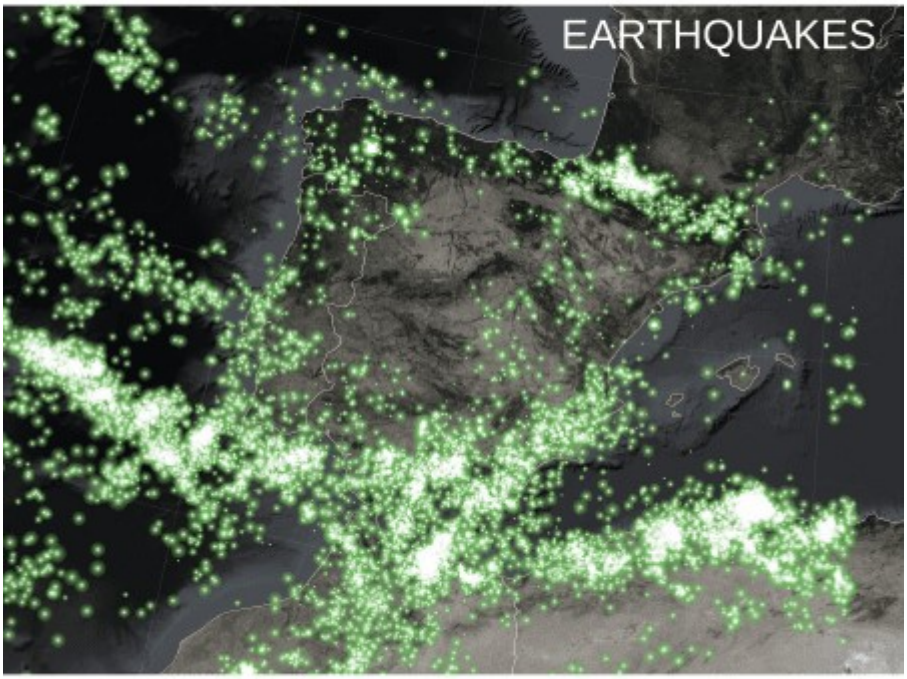
Final map

The glow effect of *firefly* maps is characterized by having a white tone or a lighter tone in the center of the points. To achieve this, we must duplicate the previous created layer, changing only the color and make the glow points smaller.

By default, `ggplot2` does not allow to use multiple scales for the same characteristic (size, color, etc) of different layers. But the `ggnewscale` package gives us the ability to incorporate multiple scales of a feature from different layers. The only important thing to achieve this is the order in which each layer (geom) and scale is added. First we must add the geometry and then its corresponding scale. We indicate with `new_scale('size')` that the next layer and scale is a new one independent of the previous one. If we used `color` or `fill` it would be done with `new_scale_*()`.

```
ggplot() +
  layer_spatial(data = stack(bm_desat)) +
  geom_sf(data = limits, fill = NA, size = .3, colour = "white") +
  geom_sf(data = grid, colour = "white", size = .1, alpha = .5) +
  geom_glowpoint(data = filter(earthquakes, mag > 3),
                 aes(geometry = geometry, size = mag),
```

```
                    alpha = .8,
                    color = "#6bb857",
                    shadowcolour = "#6bb857",
                    shadowalpha = .1,
                    stat = "sf_coordinates",
                    show.legend = FALSE) +
  scale_size(range = c(.1, 1.5)) +
  new_scale("size") +
  geom_glowpoint(data = filter(earthquakes, mag > 3),
                    aes(geometry = geometry, size = mag),
                    alpha = .6,
                    shadowalpha = .05,
                    color = "#ffffff",
                    stat = "sf_coordinates",
                    show.legend = FALSE) +
  scale_size(range = c(.01, .7)) +
  labs(title = "EARTHQUAKES") +
  coord_sf(xlim = bx[c(1, 3)], ylim = bx[c(2, 4)], crs = 3035,
           expand = FALSE) +
  theme_void() +
  theme(plot.title = element_text(size = 50, vjust = -5, colour =
"white", hjust = .95))
```




```
ggsave("firefly_map.png", width = 15, height = 15, units = "in", dpi =
300)
```