Identifying the impacts of extreme weather in Texas

Hylaea Miller

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Background

Climate change is increasing the frequency and intensity of extreme weather events, with devastating impacts. "In February 2021, the state of Texas suffered a major power crisis, which came about as a result of three severe winter storms sweeping across the United States on February 10–11, 13–17, and 15–20.

In this assignment, I identify the impacts of these series of extreme winter storms by estimating the number of homes in the Houston metropolitan area that lost power and investigate whether not these impacts were disproportionately felt.

Data

- **Night lights**: Imagery from the Visible Infrared Imaging Radiometer Suite (VIIRS) distributed through NASA's Level-1 and Atmospheric Archive & Distribution System Distributed Active Archive Center (LAADS DAAC)
- **Roads**: Data from Geofabrik's download site was used to retrieve a shapefile of all highways in Texas, and a Geopackage (.gpkg file) was prepared containing only the subset of roads that intersect the Houston metropolitan area.
- **Houses**, Data from Geofabrik's download site was used to retrieve a shapefile of all houses in Texas, and a Geopackage (.gpkg file) was prepared containing only the subset of houses that intersect the Houston metropolitan area.
- **Socioeconomic** From the U.S. Census Bureau's American Community Survey for census tracts in 2019, which contains social, economic, housing, and demographic information across the 50 states of the U.S., the District of Columbia, and Puerto Rico. The dataset can be found here: Census

Load Packages

```
# Load libraries
library(tidyverse)
library(stars)
library(sf)
library(here)
library(dplyr)
library(raster)
library(terra)
library(tmap)
library(paletteer)
```

Import Data

1. Import the datasets: Night lights (`rt`), Roads, Houses (`buildings`) and Socioeconomic

```
# Read raster tiles for both dates
# Raster tile collected 2021-02-07 - before storm
rt_0705 <- read_stars(here("data", "VNP46A1",
                           "VNP46A1.A2021038.h08v05.001.2021039064328.tif"))
rt_0706 <- read_stars(here("data", "VNP46A1",
                           "VNP46A1.A2021038.h08v06.001.2021039064329.tif"))

# Raster tile collected 2021-02-16  - after storm
rt_1605 <- read_stars(here("data", "VNP46A1",
                           "VNP46A1.A2021047.h08v05.001.2021048091106.tif"))
rt_1606 <- read_stars(here("data", "VNP46A1",
                           "VNP46A1.A2021047.h08v06.001.2021048091105.tif"))

# Read roads data
roads <- st_read(here("data",
       "gis_osm_roads_free_1.gpkg"),
  query = "SELECT * FROM gis_osm_roads_free_1 WHERE fclass='motorway'") %>%
  st_transform(crs = "epsg:3083")


# Read building data
buildings <- st_read(here("data",
                          "gis_osm_buildings_a_free_1.gpkg"),
  query = " SELECT *
```

```
    FROM gis_osm_buildings_a_free_1
    WHERE (type IS NULL AND name IS NULL)
      OR type IN ('residential', 'apartments', 'house', 'static_caravan',
  'detached')")


# Read socioeconomic data
texas_layers <- st_layers("data/ACS_2019_5YR_TRACT_48_TEXAS.gdb")

# store the layer holding the geometry information
texas_geom <- st_read("data/ACS_2019_5YR_TRACT_48_TEXAS.gdb",
                layer = "ACS_2019_5YR_TRACT_48_TEXAS")
texas_income <- st_read("data/ACS_2019_5YR_TRACT_48_TEXAS.gdb",
                        layer = "X19_INCOME",
                        query = "SELECT B19013e1, GEOID FROM X19_INCOME") %>%
  mutate(GEOID_Data = GEOID)
```

Find locations that experienced a blackout by creating a mask

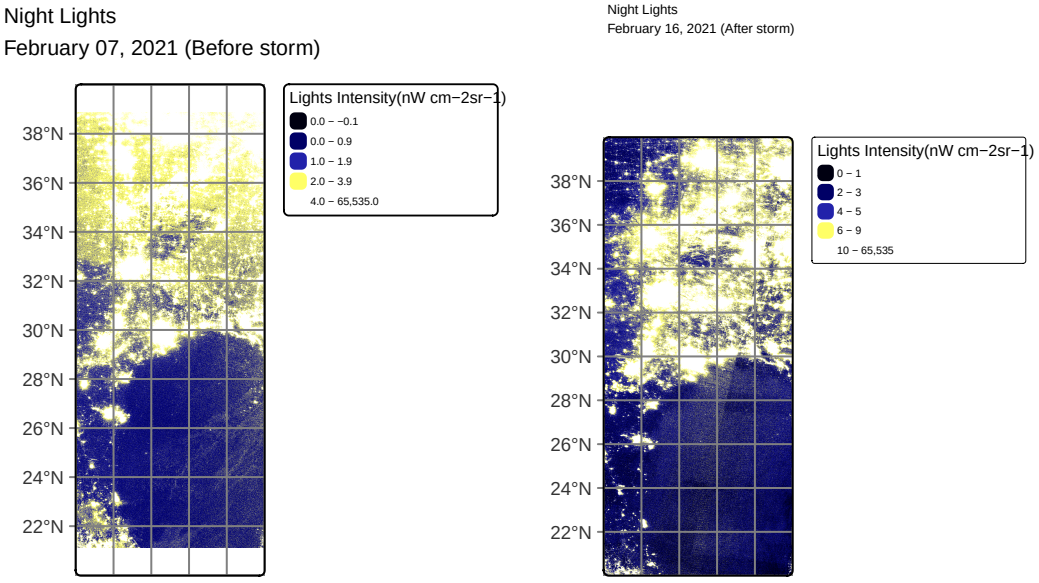
Find the change in night lights intensity (presumably) caused by the storm

```
# Join tiles
mosaic_7 <- st_mosaic(rt_0705, rt_0706)
mosaic_16 <- st_mosaic(rt_1605, rt_1606)
```

Maps comparing night light intensities before and after the storms

```
# Plot night lights after and before the storms
pal_lights <- c("#000011", "#000066", "#2222AA", "#FFFF66", "#FFFFFF")
map1 <- tm_shape(mosaic_7) +
  tm_raster(palette = pal_lights,
            style = "quantile",
            title = "Lights Intensity(nW cm-2sr-1)") +
  tm_title(text = "Night Lights\nFebruary 07, 2021 (Before storm)", size = 0.7)+
  tm_graticules()+
  tm_layout(inner.margins = c(0.001, 0.001, 0.001, 0.001),
            component.autoscale = FALSE,
            legend.text.size = 0.4,
            legend.title.size = 0.5,)

map2 <- tm_shape(mosaic_16) +
```

```
  tm_raster(palette = pal_lights,
            style = "quantile",
            title = "Lights Intensity(nW cm-2sr-1)", size = 0.6) +
  tm_title(text = "Night Lights\nFebruary 16, 2021 (After storm)")+
  tm_graticules()
  tm_layout(inner.margins = c(0.001, 0.001, 0.001, 0.001),
            component.autoscale = FALSE,
            legend.text.size = 0.4,
            legend.title.size = 0.5,)

tmap_arrange(map1, map2, nrow = 1)
```




```
# Finding changes
difference <- mosaic_7 - mosaic_16
```

```
#reclassify matrix 0 to 200
```

reclassify the difference raster, assuming that any location that experienced a drop of more than 200 nW cm-2sr-1 experienced a blackout assign NA to all locations that experienced a drop of less than 200 nW cm-2sr-1 change

```r
# Assign NA to locations that experienced a drop of less than 200 nW cm-2sr-1 change
lights_mask_diff <- difference
lights_mask_diff[difference < 200] <- NA


# vectorize mask
# mask_vec <- st_as_sf(lights_mask) %>%
#  st_make_valid()


# vectorize - st_as_sf
# st_make_valid()
# vector_difference
#st_bbox - st_as_sf or st_points
# st_intersects (st_crop)
#st_transformation
```

```r
# vectorize mask to be able to use it with the other raster

mask_vec <- st_as_sf(lights_mask_diff, as_points = FALSE, merge = TRUE) %>%
  st_make_valid() %>%
  st_as_sf(crs = 'EPSG:3083')
```

Extent match manually box the define than crop crop (spatially subset) the blackout mask to the Houston area as defined by the following coordinates: (-96.5, 29), (-96.5, 30.5), (-94.5, 30.5), (-94.5, 29)

```r
# Define coordinates of Houston
lon <- c(-96.5, -96.5, -94.5, -94.5)
lat <- c(29, 30.5, 30.5, 29)

# Create bbox from min and max of lon and lat
houston_bbox <- st_bbox(c(
  xmin = min(lon),
  ymin = min(lat),
  xmax = max(lon),
  ymax = max(lat)), crs = st_crs(mask_vec))
```

```r
cropped_blackout <-  st_crop(mask_vec, houston_bbox) %>%
st_make_valid() %>%
  st_transform(cropped_blackout, crs = "epsg:3083")
```

Maps Map number map plot

Exclude highways from analysis

st_buffer() st_src$units To dissolve polygon st_union

```
roads <-  st_transform(roads, crs = "epsg:3083")
```

```
# Check units of the highways
st_crs(roads)$units
```

```
# create a 200m buffer around highways and dissolve
roads_buffer <- st_buffer(roads, dist = 200) %>%
st_union
```

Transform coordinate reference systems to match.

```
# Check if the datasets have the same coordinate reference system.
# If not, print a warning and transform the second dataset to match the first.
if(st_crs(cropped_blackout) != st_crs(roads_buffer)){
  warning("coordinate refrence systems do not match")
  roads_buffer <- st_transform(roads_buffer, crs = st_crs(cropped_blackout))
}
```

```
# Verify that the CRS transformation was successful
print(st_crs(cropped_blackout) == st_crs(roads_buffer)) # True
```

```
# Difference, not intersection
# Blackout no in highway
cropped_blackout <- st_make_valid(cropped_blackout)
roads_buffer <- st_make_valid(roads_buffer)

blackout_not_road <- st_difference(cropped_blackout, roads_buffer)
```

```
# Using filter

# blackout_not_road <- st_filter(cropped_blackout, roads_buffer, .predicate = st_disjoint)
```

identify areas within 200m of all highways st_diff/st_disjoint (of the st_union)

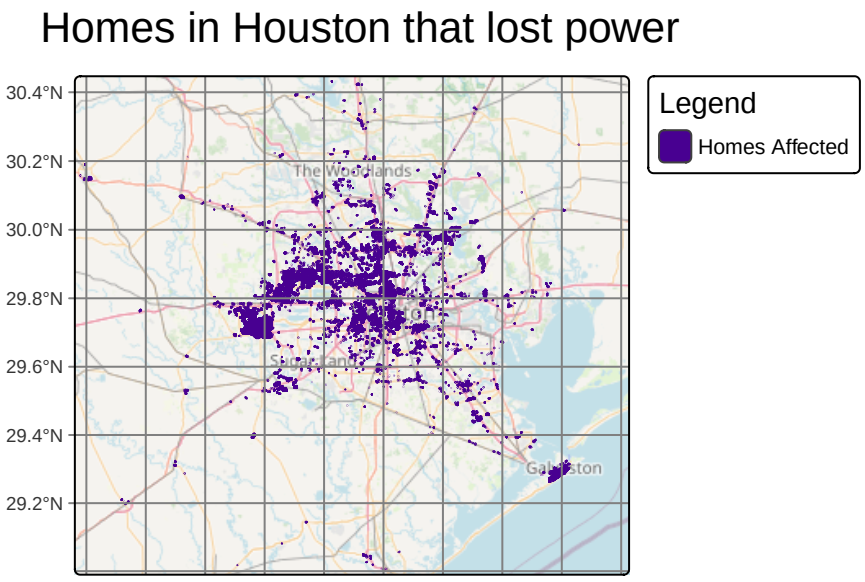
Identify homes that experienced blackouts by combining the locations of homes and blackouts

```
# Check if the datasets have the same coordinate reference system.
# If not, print a warning and transform the second dataset to match the first.
if(st_crs(blackout_not_road) != st_crs(buildings)){
  warning("coordinate refrence systems do not match")
  buildings <- st_transform(buildings, crs = st_crs(blackout_not_road))
}
```

```
homes_blackout <- buildings[blackout_not_road, # use indexing: select the rows, all columns c
                      op = st_intersects, # choose option intersect select those that share ar
                      drop = FALSE] # don't drop geometries
```

Map of the homes in Houston that lost power

```
map3 <- tm_shape(homes_blackout) +
  tm_polygons(col = "#480091") +
  tm_title(text = "Homes in Houston that lost power") +
  tm_graticules() +
  tm_basemap("OpenStreetMap", alpha = 0.7) +
  tm_layout(inner.margins = c(0.01, 0.01, 0.01, 0.1),
            component.autoscale = FALSE) +
  tm_add_legend(type = "fill",
                labels = "Homes Affected",
                col = "#480091",
                title = "Legend")

map3
```



Verify an estimate of the number of homes in Houston that lost power

```
length(homes_blackout$fclass)
```

buildings - overlap st_intersection - Houses that are partially is in the black out too Create map and summary stats

Identify the census tracts likely impacted by blackout

Join the geometry and median income layer together

```
inc_geom <- left_join(texas_geom, texas_income, by = "GEOID_Data") %>%
  st_transform(crs = "epsg:3083")
```

read social data - census track - median income read package, use query geom and income data set

```
str(texas_income)
```

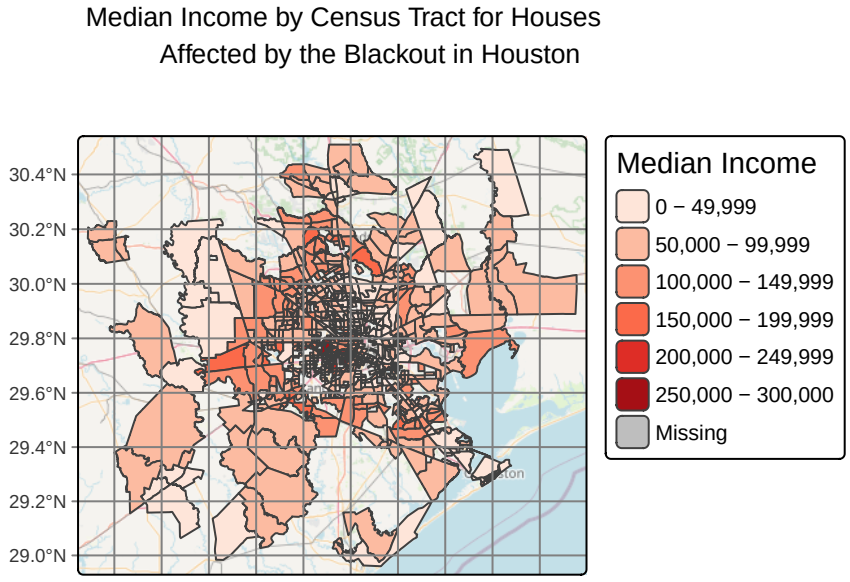
```r
# Transform CRS
houston_bbox <- houston_bbox %>%
  st_transform(crs = "epsg:3083")

# Crop census to Houston bbox
houston_income <- st_crop(inc_geom, houston_bbox) %>%
st_make_valid() %>%
  st_transform(houston_income, crs = "epsg:3083")
```

Map of the census tracts in Houston that lost power

```r
# Intersect income census with homesst_intersect (consider houses partially inside)
homes_census <- houston_income[homes_blackout,
                               op = st_intersects]
```

socioecon - layer 1 (geoms)and layer 2 (income)- left_join by geo id st_transform st_join

```r
# Visualize the distribution of blackout areas over a map of median income in Houston
tm_shape(homes_census) +
  tm_polygons(
    col = "B19013e1",
    palette = "Reds",
    title = "Median Income") +
 tm_basemap("OpenStreetMap", alpha = 0.7) +
 tm_graticules() +
 tm_title(text = "Median Income by Census Tract for Houses
          Affected by the Blackout in Houston" )
```



Find census tracts that did not experience blackout

data wrangling to summarize median income by census track

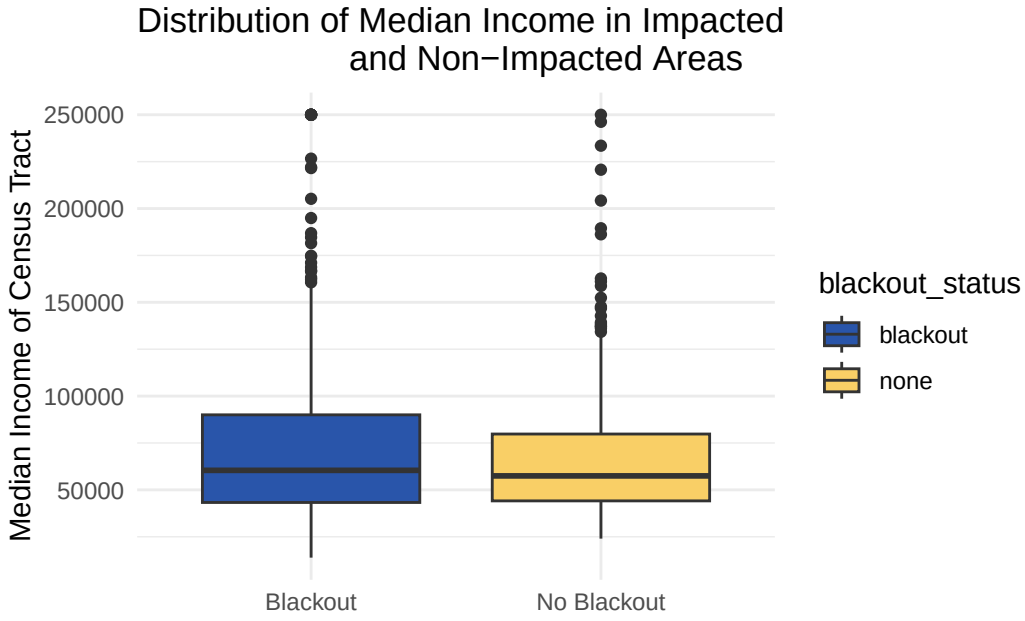
Select values from houston_income that are not in building_census (census tracts with blackouts)

```
# Add blackout status to all tracts at once
census_combined <- houston_income %>%
  mutate(blackout_status = if_else(GEOID_Data %in% homes_census$GEOID_Data,
                                   "blackout", "none")) %>%
  st_drop_geometry() %>%
  dplyr::select(B19013e1, blackout_status) %>%
  drop_na()
```

Plot comparing the distributions of median household income for census tracts that did and did not experience blackouts

```
# plot the distribution of median income in impacted and not impacted census tracts that did
ggplot() +
  geom_boxplot(data = census_combined,
           aes(x = blackout_status,
```

```
              y = B19013e1,
              fill = blackout_status)) +
scale_x_discrete(labels=c("Blackout", "No Blackout")) +
scale_fill_manual(values = c("#2955AA", "#F9cF66")) +
labs(x = "",
     y = "Median Income of Census Tract",
     title = "Distribution of Median Income in Impacted
                    and Non-Impacted Areas") +
theme_minimal()
```



Look out of houston - no black out were census layer

Reflection

Data Citations

Home - LAADS DAAC. (2017, February 22). Nasa.gov. https://ladsweb.modaps.eosdis.nasa.gov/

Download OpenStreetMap for OpenStreetMap Data Extracts | Geofabrik Download Server. (2025). Geofabrik Download Server. https://download.geofabrik.de/

Bureau, U. C. (2025, September 29). American Community Survey (ACS). Census.gov. https://www.census.gov/programs-surveys/acs